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- Sensory/Mental Health** (top right)
- Bone & Muscle Health** (bottom left)
- Digestive Health** (bottom center)
- Vital Organ Health** (bottom center)
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mind and body from dawn to dusk. All the while, making the term "confined to a wheelchair" absolutely irrelevant. Meet Fritzie. An eight-year-old Yellow Lab



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Thank you, Aunt Jessie. She's the one who gave me a subscription to *Sky & Telescope* magazine when I was a boy. I devoured every issue, and so began my lifelong obsession with the stars. By the seventh grade I was poking holes in slides to project constellations on the wall.

That was the '50s, only three decades after the existence of galaxies outside the Milky Way had been proved. Our understanding of galaxies has exploded since then, but to astronomy fans like me, the advances of the past half century aren't nearly as astonishing as the surge of new insights in the past few years. Orbiting telescopes have let us see phenomena like this galaxy with a tail that astronomers call the Tadpole, and powerful computers have let us model a galaxy's very birth.

Turn to page 2 for a new look at galaxies. And when you're done with this issue, show it to a kid. You never know what you might start.

Bill Allen

HUBBLE SPACE TELESCOPE IMAGE: HOLLAND FORD, JOHNS HOPKINS UNIVERSITY; GARTH ILLINGWORTH, UNIVERSITY OF CALIFORNIA, SANTA CRUZ/LICK OBSERVATORY; MARK CLAMPIN AND GEORGE HARTIG, SPACE TELESCOPE SCIENCE INSTITUTE/ADVANCED CAMERA FOR SURVEYS TEAM; NASA; EUROPEAN SPACE AGENCY

■ Watch my preview of the March issue on *National Geographic Today* on February 17 at 7 p.m. and again at 10 p.m. (ET and PT)—only on the National Geographic Channel.

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FOR PEOPLE WITH TYPE 2 DIABETES

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“Every big hug makes me glad I take care of my diabetes.”

“My granddaughter sure knows how to make my day. Her face lights up when she sees me. Then, she dishes out those hugs—and *that’s* what really makes me want to take care of my diabetes.

“I’ve got my routine down: I stay active, and try my best to eat healthier meals. To help me stay on track, my doctor added *Avandia*. It makes my body more responsive to its own natural insulin, so I can control my blood sugar more effectively.

“I started on *Avandia* over a year ago. And while not everyone gets the same results, my blood sugar has never been better. I know *Avandia* is helping me to be stronger than diabetes. That’s something I can really wrap my arms around.”

Avandia, along with diet and exercise, helps improve blood sugar control. It may be prescribed alone, with Glucophage® (metformin HCl tablets) or with sulfonylureas. When taking *Avandia* with a sulfonylurea, you may be at risk for low blood sugar. Ask your doctor whether you need to lower your sulfonylurea dosage.

Some people may experience tiredness, weight gain or swelling with *Avandia*.

Avandia in combination with insulin may increase the risk of serious heart problems. Because of this, talk to your doctor before using *Avandia* and insulin together. *Avandia* may cause fluid retention, or swelling, which could lead to or worsen heart failure, so tell your doctor if you have a history of these conditions. If you experience an unusually rapid increase in weight, swelling or shortness of breath while taking *Avandia*, talk to your doctor immediately. *Avandia* is not for everyone. If you have severe heart failure or active liver disease, *Avandia* is not recommended.

Also, blood tests to check for serious liver problems should be conducted before and during *Avandia* therapy. Tell your doctor if you have liver disease, or if you experience unexplained tiredness, stomach problems, dark urine or yellowing of the skin while taking *Avandia*.

If you are nursing, pregnant or thinking about becoming pregnant, or if you are a premenopausal woman who is not ovulating, talk to your doctor before taking *Avandia*.

See important patient information on the adjacent page.

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Patient Information about AVANDIA® (rosiglitazone maleate) 2 mg, 4 mg, and 8 mg Tablets

What is *Avandia*?

Avandia is one product in a class of prescription drugs called thiazolidinediones (thigh-a-zol-a-deen-die-owns) or TZDs. It is used to treat type 2 diabetes by helping the body use the insulin that it is already making. *Avandia* comes as pills that can be taken either once a day or twice a day to help improve blood sugar levels.

How does *Avandia* treat type 2 diabetes?

If you have type 2 diabetes, your body probably still produces insulin but it is not able to use the insulin efficiently. Insulin is needed to allow sugar to be carried from the bloodstream into many cells of the body for energy. If insulin is not being used correctly, sugar does not enter the cells very well and builds up in the blood. If not controlled, the high blood sugar level can lead to serious medical problems, including kidney damage, blindness and amputation.

Avandia helps your body use insulin by making the cells more sensitive to insulin so that the sugar can enter the cell.

How quickly will *Avandia* begin to work?

Avandia begins to reduce blood sugar levels within 2 weeks. However, since *Avandia* works to address an important underlying cause of type 2 diabetes, insulin resistance, it may take 8 to 12 weeks to see the full effect. If you do not respond adequately to your starting dose of *Avandia*, your physician may increase your daily dose to improve your blood sugar control.

How should I take *Avandia*?

Your doctor may tell you to take *Avandia* once a day or twice a day (in the morning and evening). It can be taken with or without meals. Food does not affect how *Avandia* works. To help you remember to take *Avandia*, you may want to take it at the same time every day.

What if I miss a dose?

If your doctor has prescribed *Avandia* for use once a day:

- As soon as you remember your missed dose, take one tablet anytime during the day.
- If you forget and go a whole day without taking a dose, don't try to make it up by adding another dose on the following day. Forget about the missed dose and simply follow your normal schedule.

If your doctor has prescribed *Avandia* for use twice a day:

- As soon as you remember the missed dose, take one tablet.
- Take the next dose at the normal time on the same day.
- Don't try to make up a missed dose from the day before.
- You should never take three doses on any single day in order to make up for a missed dose the day before.

Do I need to test my blood for sugar while using *Avandia*?

Yes, you should follow your doctor's instructions about your at-home testing schedule.

Does *Avandia* cure type 2 diabetes?

Currently there is no cure for diabetes. The only way to avoid the effects of the disease is to maintain good blood sugar control by following your doctor's advice for diet, exercise, weight control, and medication. *Avandia*, alone or in combination with other antidiabetic drugs (i.e., sulfonylureas or metformin), may improve these other efforts by helping your body make better use of the insulin it already produces.

Can I take *Avandia* with other medications?

Avandia has been taken safely by people using other medications, including other antidiabetic medications, birth control pills, warfarin (a blood thinner), Zantac® (ranitidine, an antiulcer product from GlaxoSmithKline), certain heart medications, and some cholesterol-lowering products. You should discuss with your doctor the most appropriate plan for you. If you are taking prescription or over-the-counter products for your diabetes or for conditions other than diabetes, be sure to tell your doctor. Sometimes a patient who is taking two antidiabetic medications each day can become irritable, lightheaded or excessively tired. Tell your doctor if this occurs; your blood sugar levels may be dropping too low, and the dose of your medication may need to be reduced.

What should I discuss with my doctor before taking *Avandia*?

Avandia in combination with insulin may increase the risk of serious heart problems. Because of this, talk to your doctor before using *Avandia* and insulin together. *Avandia* may cause fluid retention or swelling which could lead to or worsen heart failure, so tell your doctor if you have a history of these conditions. You should also talk to your doctor if you have liver problems, or if you are nursing, pregnant or thinking of becoming pregnant. If you are a premenopausal woman who is not ovulating, you should know that *Avandia* therapy may result in the resumption of ovulation, which may increase your chances of becoming pregnant. Therefore, you may need to consider birth control options.

What are the possible side effects of *Avandia*?

Avandia was generally well tolerated in clinical trials. The most common side effects reported by people taking *Avandia* were upper respiratory infection (cold-like symptoms) and headache. As with most other diabetes medications, you may experience an increase in weight. You may also experience edema (swelling) and/or anemia (tiredness). If you experience any swelling of your extremities (e.g., legs, ankles) or tiredness, notify your doctor. Talk to your doctor immediately if you experience edema, shortness of breath, an unusually rapid increase in weight, or other symptoms of heart failure.

Who should not use *Avandia*?

You should not take *Avandia* if you are in the later stages of heart failure or if you have active liver disease. The following people should also not take *Avandia*: People with type 1 diabetes, people who experienced yellowing of the skin with Rezulin® (troglitazone, Parke-Davis), people who are allergic to *Avandia* or any of its components and people with diabetic ketoacidosis.

Why are laboratory tests recommended?

Your doctor may conduct blood tests to measure your blood sugar control. Blood tests to check for serious liver problems should be conducted before starting *Avandia*, every 2 months during the first year, and periodically thereafter.

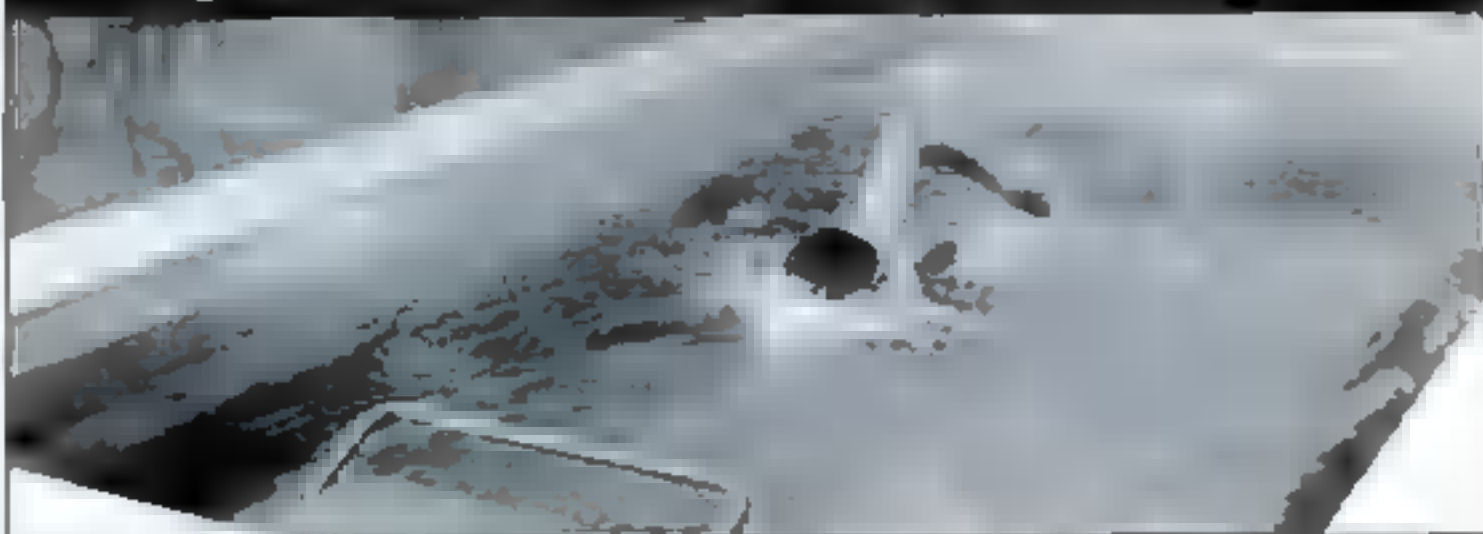
It is important that you call your doctor immediately if you experience unexplained symptoms of nausea, vomiting, stomach pain, tiredness, anorexia, dark urine, or yellowing of the skin.

How should I store *Avandia*?

Avandia should be stored at room temperature in a childproof container out of the reach of children. Store *Avandia* in its original container.



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A lawsuit is pending in the Circuit Court of Madison County, Illinois and is entitled *Strasen v. Allstate Insurance Company*, No. 99 L 1040. This Notice is directed to all members of the Plaintiff Class.

CLASS ACTION NOTICE

TO: All Persons Who Fit Either of The Following Two Descriptions ("the Plaintiff Class").

- (1) Persons who, as drivers or passengers in a vehicle insured by Allstate, were injured in an auto accident, and thereafter submitted a claim to Allstate for payment of medical expenses; Or,
- (2) Medical providers who treated the injuries of the persons described in (1), and Who Received An Assignment of an Insured's rights regarding claims for payment of medical expenses.

This notice may affect your legal rights. You may be a member of the Plaintiff Class who is pursuing money damages against their assertion that Allstate improperly handled their claims for payment of medical expenses between October 26, 2001 and the present. You should carefully read this Notice to determine if you are a member of the Plaintiff Class in this case.

The Class Claims: Plaintiff alleges that Allstate breached its insurance policy contracts: (1) by improperly reducing claims that were submitted under the Medical Payments/Personal Injury Protection (collectively, "Medpay") portions of Allstate's automobile insurance policies, and (2) by using biased ADP Integrated Medical Solutions computer reports to adjust Medpay claims. Plaintiff seeks damages against Allstate including but not limited to the amount by which Allstate reduced each Medpay claim. Allstate denies the allegations and denies that it has any liability to the Plaintiff Class. Although the Court has determined that the case may proceed as a class action, that ruling does not mean that the Court made any determination about the merits of Plaintiff's allegations or Allstate's defenses.

Class Representation: The Court has appointed Dennis Strasen as Class Representative and his lawyers as Class Counsel. You will not be charged for their services. Instead, if they obtain a recovery for the Class, Counsel will apply to the Court for payment of attorneys' fees and costs.

How do I participate in the Class? If you wish to remain a member of the Class, YOU NEED NOT DO ANYTHING AT THIS TIME. As a class member, you will be bound by the Court's orders and judgments. You also have the right to seek the Court's permission to intervene or appear in the action.

How do I exclude myself from the Class? You may exclude yourself from the class by mailing a signed letter requesting exclusion to **Allstate Medpay Litigation**, P.O. Box. 229, Wood River, Illinois 62296. Such request must be postmarked by March 21, 2003. If you exclude yourself from the Class, you cannot participate in any recovery for the Class. You will not be bound by any Court orders or judgments. You also have the right to seek the Court's permission to intervene or appear in the action.

This Notice is only a summary of this action. If you would like further information or have questions regarding this case, you may write to the above address or go on-line to www.freedweiss.com/allstate or www.lakinlaw.com/allstate. PLEASE DO NOT TELEPHONE OR ADDRESS INQUIRIES TO THE COURT.

DATED: November 15, 2002. By Order of the Circuit Court of Madison County, Illinois.

Get caught reading.

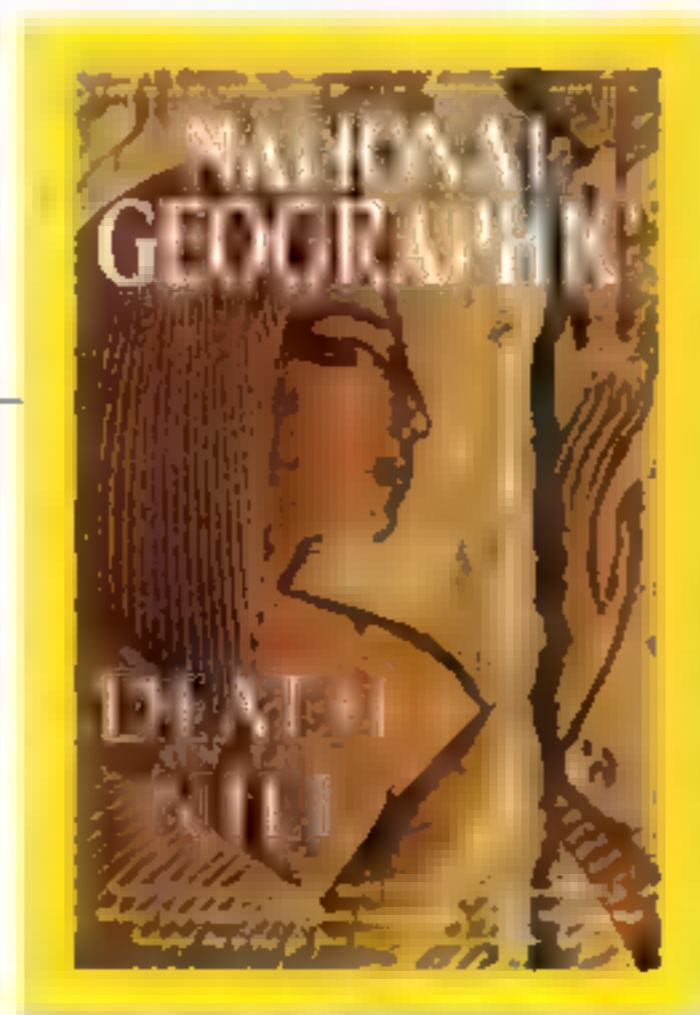
JEFFERSON and ADAMS

Vernon Jordan gets caught reading.

Forum

October 2002

The West Bank article generated a torrent of letters (the most received in response to any story since 1998). Most of them questioned the story's facts and accused the author of an anti-Israel bias. The facts in every GEOGRAPHIC story are thoroughly checked before publication, and experts—representing different points of view—review texts for accuracy. We stand by the West Bank article.



In Focus: The West Bank

Andrew Cockburn should have titled his article "Israelis Bad, Palestinians Good." In his view of the Middle East, every action taken over the past half century by the Israelis is a cold, calculated attempt to take advantage of the Palestinians, and every action by the Palestinians is a reasonable response to the oppression by the Israelis. No attempt is made to explain why the Israelis have fought so ferociously to defend themselves. For example, not a single reference is made to the fact that the Palestinians and every country on Israel's borders have vowed, until recently, to destroy Israel.

STEVE JEFFRIES
Foster City, California

I commend you for your courage in being the first major U.S. publication to accurately report on the problems that have resulted in so much violence and suffering for both Palestinians

and Israelis. You will be severely criticized by some for having told the unvarnished truth, painful as it may be.

DAVID P. CARROLL
Brooklyn, New York

As someone who was living in Israel during the 1973 Yom Kippur War, I am surprised that the article gave that period of Israeli history such short shrift. The entire article is skewed to portray Israel as the supreme villain and aggressor in the Middle East. It neglects to mention the massacres that occurred in 1929 and 1936 by Arabs against Jews. It describes the Israeli Army of 1948 as well equipped, which would be amusing if so many Jews had not died. Jordan did manage to take the West Bank, if you recall. Anyone who has handled "Czecki" rifles, which were received from Czechoslovakia with great effort, will laugh at your description.

SYLVIA NAVON
New York, New York

Israeli settlements are not in violation of international law. Israel's administration of the territory in 1967 replaced Jordan's control of the West Bank and Egypt's of the Gaza Strip.



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Hotspot: New Zealand

A typical Kiwi kid, I spent my childhood tearing about the sandy shores just south of Auckland. Every day I was surrounded by the biodiversity of this country. Tuis, wood pigeons, fantails, kakas, wetas, lizards, and goodness knows what else made regular appearances in the bush around our house. One of my favorite memories is coming nose-to-beak with a group of keas on the South Island: Once they became bored with our car, they devised a game that involved throwing a glass bottle to one another, then rolling it down the road and chasing it. It is great to see how much is being done to preserve our unique wildlife and flora. It is distressing to think that my grandchildren might not have the opportunity to wake up to

the call of the tui and the smell of the New Zealand bush.

KIRSTIN FOSTER
Auckland, New Zealand

The kea is not the killer people once thought it to be. Farmers would see keas on the backs of sheep and accuse them of killing sheep. Many keas were shot as a consequence.

The kea is indeed a very cheeky bird. If you park your car where the kea can get at it, you risk the loss of rubber seals around the windows and mirrors.

GRAHAM KAYWOOD
Waikanae, New Zealand

You indicated that New Zealand has 68 endemic species of birds and only three mammals



FRANS IANTING

(all bats). As a marine biologist, I can't help but think that this view is overly terrestrial. New Zealand has endemic marine mammals as well: Hector's dolphins and New Zealand sea lions. And many of the bird species are as marine as they are terrestrial—petrels, penguins, and shearwaters, for example.

MICHAEL WEBSTER
*Department of Zoology
Oregon State University
Corvallis, Oregon*

Neither Jordan nor Egypt had legal sovereignty over these areas. Israel thus did not "occupy" these areas from another sovereign nation, but assumed control of "disputed territories" over which there are competing claims, and whose future must be determined through negotiations. Similarly, much of the international law referred to by critics of Israel relates to the forcible transfer of segments of a population of a state to the territory of another state which it has occupied through the use

of armed force. The situation in the West Bank and Gaza Strip is clearly different. Israel has not forcibly transferred Israelis to these disputed areas. Rather, Israeli settlers voluntarily reside in areas where Jews have historically dwelled.

ABRAHAM H. FOXMAN
*National Director
Anti-Defamation League
New York, New York*

FROM OUR ONLINE FORUM
nationalgeographic.com/ngm/0210

As an American who recently returned from two years in the Gaza Strip, I found the article to be a remarkably objective and balanced portrayal.

NATHAN STOCK
Forcstville, New York

You failed to point out that from 1948 to 1967 no Palestinian state

was created when Jordan occupied the West Bank.

MARTIN I. SALTZMAN
Beachwood, Ohio

Middle East Map

Zoroastrians and Christians aren't Iran's only religious minorities. Baha'is are the country's largest religious minority.

VAFA AFLATOONI
Pendleton, Oregon

You may be right. About 300,000 members of the long-persecuted faith, which began as a reformist movement within Shiite Islam in 1844, may still live in Iran.

Death on the Nile

I protest the description of Ankhesenpepi II as "alluring, savvy, ruthless." The sexist tone is especially obvious when compared with the author's praise

WRITE TO FORUM

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for Horemheb as a man “who maneuvered successfully through the politics of Akhenaten’s time.” Both rulers found themselves in similar situations. Ankhesenpepi married Merenre, son of Pepi I; some scholars believe that Horemheb married one of Akhenaten’s daughters. I do not find it alluring or ruthless of Ankhesenpepi to attempt to keep the throne for her nephew or her son—only savvy. Scholars also believe that marrying relatives was a well-established custom in the Egyptian royal lines because legitimacy to the throne actually carried through the female line. Does that make Ankhesenpepi’s husband hunky, savvy, and ruthless?

SUSAN J. BRIDGES
New York, New York

ZipUSA: Hibbing, Minnesota

Thank you for featuring my hometown. I grew up in Hibbing, but like most kids I moved away to go to college. I had to laugh about the visit to Jimmy’s and how the crowd got a little angry. You’re right, they don’t like out-of-towners. [See the October 2002 Field Notes in the Archives at *nationalgeographic.com/ngm*.] Some of the guys up there are mean if they’ve been drinkin’. That town has been through hard times. Hibbing should have died many times over, but it keeps on going. The people in Hibbing are a rare lot—strong, stubborn, and stoic. I’m proud to be from the Iron Range.

ANNMARIE GRIFFITHS
Boston, Massachusetts

World Heritage Sites

I was recently at Cocos Island, Costa Rica, a World Heritage site, scuba diving. Illegal shark fishing has increased dramatically. A few weeks before our

arrival, poachers burned the patrol boats of the rangers who are trying to protect this sanctuary. I was appalled to witness the trash and discarded fishing line heaved overboard by these poachers. If the protection of this site is not enforced immediately, it will cease to exist as a

The West Bank article should have been titled “Israelis Bad, Palestinians Good.” In your view, every action taken by the Israelis is a cold, calculated attempt to take advantage of the Palestinians.

world-class marine sanctuary and become just another overfished island.

JOHN R. MUNRO
Crossville, Tennessee

I thoroughly enjoyed the UNESCO list of World Heritage sites. However, I didn’t realize that Jerusalem was not a part of Israel. The last time I checked, it was the capital (at least that’s what the Middle East map in the same issue states).

EVAN D. FINEMAN
Somerville, Massachusetts

We followed the UNESCO World Heritage List.

Istanbul

Some of the Western media clearly operate with a double

standard. When it comes to cities such as Rome, Paris, Athens, and Brussels, Western media describe them as the best cities and proper vacation destinations. These cities have many troubles, but nobody mentions them. When it comes to Istanbul, the message is: Turkey is a Third World Islamic country, so don’t go there. Turkey is a modern country with a secular government. Yes, there are conservative movements there, as there are all around the world, including Western countries like France, Italy, and the United States. Instead of describing Istanbul as an undeveloped city with a lot of fundamentalist Muslims and other problems, you could have described the countless five-star hotels, the Bosphorus bridges, nightclubs, shopping malls, cafés, museums, marinas, and its rich cuisine.

DENIZ CETINER
Washington, D.C.

Behind the Scenes

As someone who has traveled throughout the world to a great many underprivileged countries, I found “Reader Fixes an African Bridge” to be inspiring. At a time when there is so much destruction, it is nice to know there are people willing to construct rather than destroy. Is there a website or address where I can get more information or make a donation?

JENNIFER ELLIOTT
Alamo, California

Bridges to Prosperity’s address and website are: 1674 Cuba Island Lane, Hayes, VA 23072; bridgestoprosperty.org.

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A photograph of Dorothy Hamill ice skating on a snowy mountain slope. She is wearing a blue puffer vest over a black jacket and black pants. She is smiling and has her right arm raised in a graceful pose. The background shows snow-covered mountains and evergreen trees under a bright sky.

DOROTHY HAMILL

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IRAQ

The Sum of Its Parts

Diversity in a desert land

On a mountain in northwestern Iraq stands a modest temple with a cone-shaped steeple. It is a shrine of the Yazidis, a sect that practices angel worship.

Yazidis are one example of Iraq's diversity of peoples and faiths. When Iraq was created out of parts of the defeated Ottoman Empire after World War I—first as a British protectorate, but independent since 1932—it brought together Assyrian Christians still worshipping in Aramaic, the language of Jesus; Turkomans whose ancestors arrived in the 13th century with the conqueror Tamerlane; and a community of Jews in Baghdad. Then and now, the dominant groups are Kurds and Arabs who practice both Sunni and Shiite Islam.

The at times fractious relationships among these major groups will be pivotal to Iraq's future.

Northern mountain ranges have long sheltered the Kurds, a resilient people who have never had a politically recognized homeland. Iraq's largest minority—17 percent of the 24 million people—had their first chance to run their own affairs after Saddam Hussein's army withdrew in 1991, in the aftermath of the Persian Gulf war. Funds collected from Iraqi oil revenue by the UN have paid for food, medicine, new roads, and schools. Kurdish leaders want autonomy in an Iraqi federal state. If it doesn't come to be, Kurds may attempt to win outright independence.



Much of Iraq south of the mountains is empty desert. The population huddles close to the Tigris (below) and Euphrates, as did the Sumerians and other

ancients of Mesopotamia. The population is largely urban; the capital, Baghdad, alone is home to five million people.

Baghdad is also the citadel of Arab Sunni Muslims. Bureaucrats since Ottoman days, they are a well-educated elite accustomed to power—although outnumbered three to one by the less urban Shiites.

Poorer than Sunnis, the Shiites are also more devoted to religious leaders. Shrines in Karbala and An Najaf hold the remains of martyrs slaughtered in the Islamic schism that wrenched control of the faith from Muhammad's kin in A.D. 680. The Shiites—the losing side in that violent episode—revere these shrines almost as much as they do Mecca.

Saddam, wary of Iraqi Shiites' ties to Iranian Shiites, viciously cracked down on the Iraqi Shiites in the 1970s. They rose against him as the gulf war ended in 1991, only to be put down again.

In a future Iraq, freed from Saddam's dictatorship, the Shiites, like the Kurds, might pursue a federal system giving them control over their own affairs. It wouldn't be achieved easily; political autonomy is a novel concept in historically autocratic Iraq. But such a change might weld Iraq's diverse pieces into a united nation—perhaps even a peaceful one. —Mike Edwards



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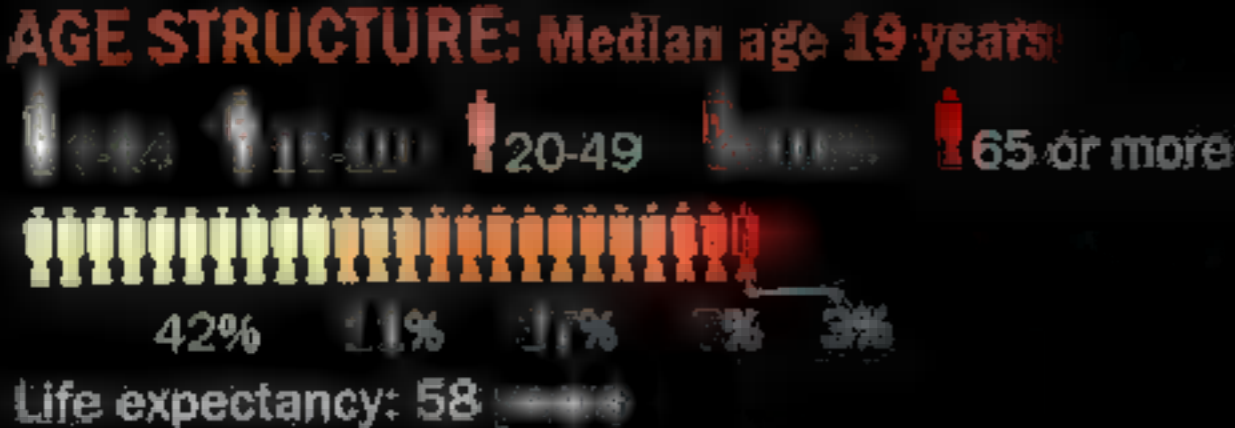
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The Tigris and Euphrates
 Because of its dependence on these rivers, Iraq faces a critical water shortage that will worsen when Turkey completes a score of irrigation projects and dams.

River
 Home of 25 million Kurds, the realm called Kurdistan sprawls into more than four million Kurds are one of the world's largest groups of stateless peoples.

Marsh Arab
 The construction of canals and dams by Saddam broke up the home of the Shi-Marsh Arabs. These wetlands are almost vanished; many Marsh Arabs now live in refugee camps in Iran.



SOURCE: LANDSCAN GLOBAL POPULATION DATA, NATIONAL LABORATORY, NG MAPS

MIGRATIONS

Pachyderms Hit the Road

Desert elephants need sustenance, will travel



IAIN DOUGLAS-HAMILTON

South of Timbuktu, in the Gourma region of the Malian Sahel, some unusual elephants are taking great strides. These beasts eke out a living at the northern extreme of the African elephant's distribution, showing remarkable adaptations to their desert environment. Scientists are intrigued by the animals' incredible journeys, which can cover an area

twice that of other elephants. "Theirs puts all other elephant migrations in the shade," says Iain Douglas-Hamilton of Kenya's Save the Elephants, who, with the Wildlife Conservation Society's Stephen Blake and other colleagues, studied their movements.

Nine elephants were radio collared, but only three collars yielded data. A male's route doubled back on itself; two females made counterclockwise sweeps of

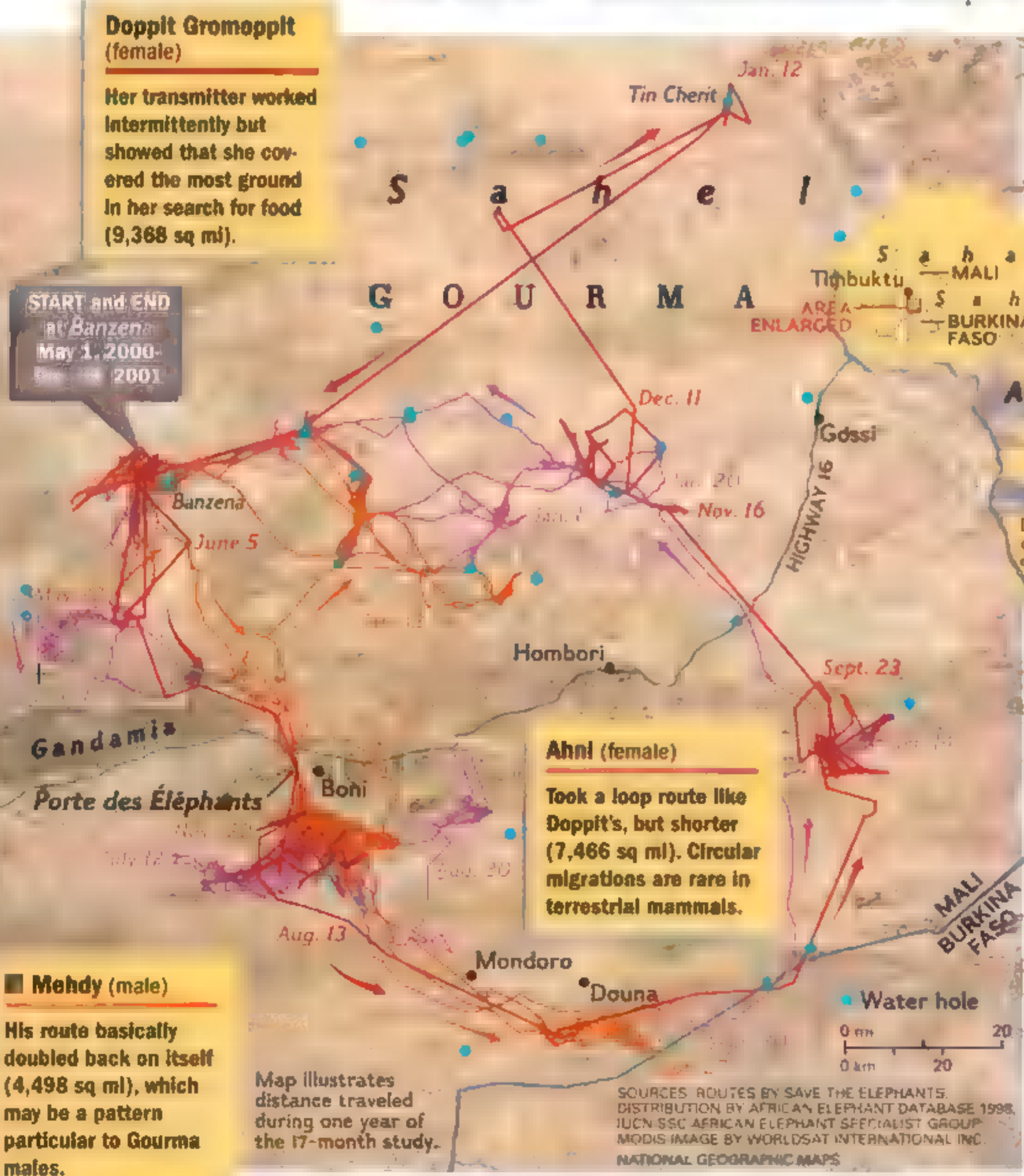
the landscape (one's home range topped 9,000 square miles)—a donut formation unique to these elephants that may allow them to skirt urban areas (map). All three followed the rains, eating and drinking their way from water hole to water hole. And since desert pools can dry up in a heartbeat, says Douglas-Hamilton, "it's absolutely critical that they get the timing right."

The 325 or so Gourma elephants are a remnant group of a once widespread Sahelian population. They owe their survival largely to Mali's Tuareg and Peul herdsmen, who allow the elephants access to natural

resources. "Human attitudes are the ultimate determinant for these animals," Douglas-Hamilton says. "With less tolerant people, they'd be wiped out."

Still, climate change and desertification are degrading already meager habitat, and well-meaning development encourages permanent settlements and intensive livestock grazing—bad for the pachyderms. "Their position is highly precarious," says Douglas-Hamilton. "Without wise land planning, it's curtains for these unique elephants."

—Jennifer Steinberg



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THEREMINS THROUGH TIME



1919 Leon Theremin (above) invents the theremin in the Soviet Union. It was one of the first electronic musical instruments.

1936 Percy Grainger composes his four-theremin "Free Music 1."



JOHN SPRINGER COLLECTION/CORBIS

1976 Jimmy Page plays theremin in a Led Zeppelin concert film.

1993 Leon Theremin dies in Moscow at the age of 97.

1928 The inventor is granted a U.S. patent for the instrument.



NEW YORK PUBLIC LIBRARY

1951 A theremin's wail announces aliens in *The Day the Earth Stood Still*.

1966 Beach Boys' "Good Vibrations" includes electro-theremin.



BETTMANN/CORBIS

2002 Steve Nieve plays theremin on tour with Elvis Costello.

TECHNOLOGY

Revenge of the Theremin

It's not just for sci-fi soundtracks anymore

Eight decades after its invention, one of the earliest electronic instruments is popular again.

To play the theremin, a musician's hands hover around the instrument's antennas, controlling pitch and volume by interrupting the electromagnetic fields that surround them (that's why photographer Landon Nordeman couldn't get too close while shooting Laura Oggar performing with the Novellas in New York, above).

The theremin produces wavering notes—*ooh-wee-oooh*—that sound more like George Jetson than George Gershwin. You may have heard it in Led Zeppelin's "Whole Lotta Love." But that's not a theremin in the Beach Boys' "Good Vibrations"; it's the

electro-theremin—based on the same principles but laid out like a keyboard.

Remembering which hand position produces what note isn't easy. Inventor Leon Theremin taught the technique in the United States in the 1920s after a series of concerts. He'd already made a splash in his native Soviet Union, giving demonstrations to admirers including Vladimir Lenin.

Build-your-own-theremin kits are now widely available. And Moog Music, a company specializing in electronic instruments, sold more than 3,100 ready-made theremins in 2001. "It's kind of a cult thing," says Moog's Linda Pritchard, "but more people seem to want them every year."

—Margaret G. Zackowitz

LANDON NORDEMAN (ABOVE); HULTON DEUTSCH COLLECTION; CORBIS (LEFT)



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SARAH LEEN (ABOVE); AMERICAN RED CROSS (BELOW)

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Here it comes, a special collector's edition you never expected to see: the NATIONAL GEOGRAPHIC swimsuit issue. Really.

"For more than a century, our mission has been to cover 'the world and all that is in it,'" says Editor in Chief Bill Allen. "Even if everything in it wasn't very well covered."

When Bill asked the magazine's photo editors to review images of bathing beauties, water-skiers, and beachcombers, the photos

they came up with, most from our archives, formed a fascinating study of changing mores.

"Sure, we're having fun, but there's a serious, informative side to this," says Maggie Zackowitz, the issue's text editor. "You can see cultural change in the evolution of swimsuits. In the 1800s people didn't swim, they bathed. That's why what they wore were called bathing suits. There weren't many swimming pools, and women weren't supposed to exercise."

The earliest photo, of a bold Red Cross swimming instructor



(above), dates from 1900; the latest, of surfers in Hawaii (top), was made last year. The issue, available on newsstands and in bookstores February 1, can be ordered online (nationalgeographic.com/ngm/swimsuits) through April. It's all about what Bill Allen calls "a sense of fun and wonder—as well as total astonishment at what some people will wear in public."

zoom-zoom

www.mazdaUSA.com/newmazda6





Alterations in the Andes

Reweaving old ways

They gather by the hundreds at 14,000 feet above sea level in the Peruvian Andes—alpaca herders, potato farmers, and weavers—for annual festivals that originated in Inca times or even earlier. For such a special day, they weave and wear their most beautiful, colorful garments (right). Master weaver Nilda Callañaupa—a native of the region and the founder of the Center for Traditional Textiles of Cusco—documented two such festivals with the aid of a



JOHN BACOLO

National Geographic Society Expeditions Council grant and found the modern world starting to intrude. “Younger weavers now are buying brightly colored

commercial yarn instead of spinning their own naturally dyed alpaca yarn,” she says. “They consider the flashy colors fashionable.”

High-flying Bridgework

Photo aids dentist's quest to help wounded warrior

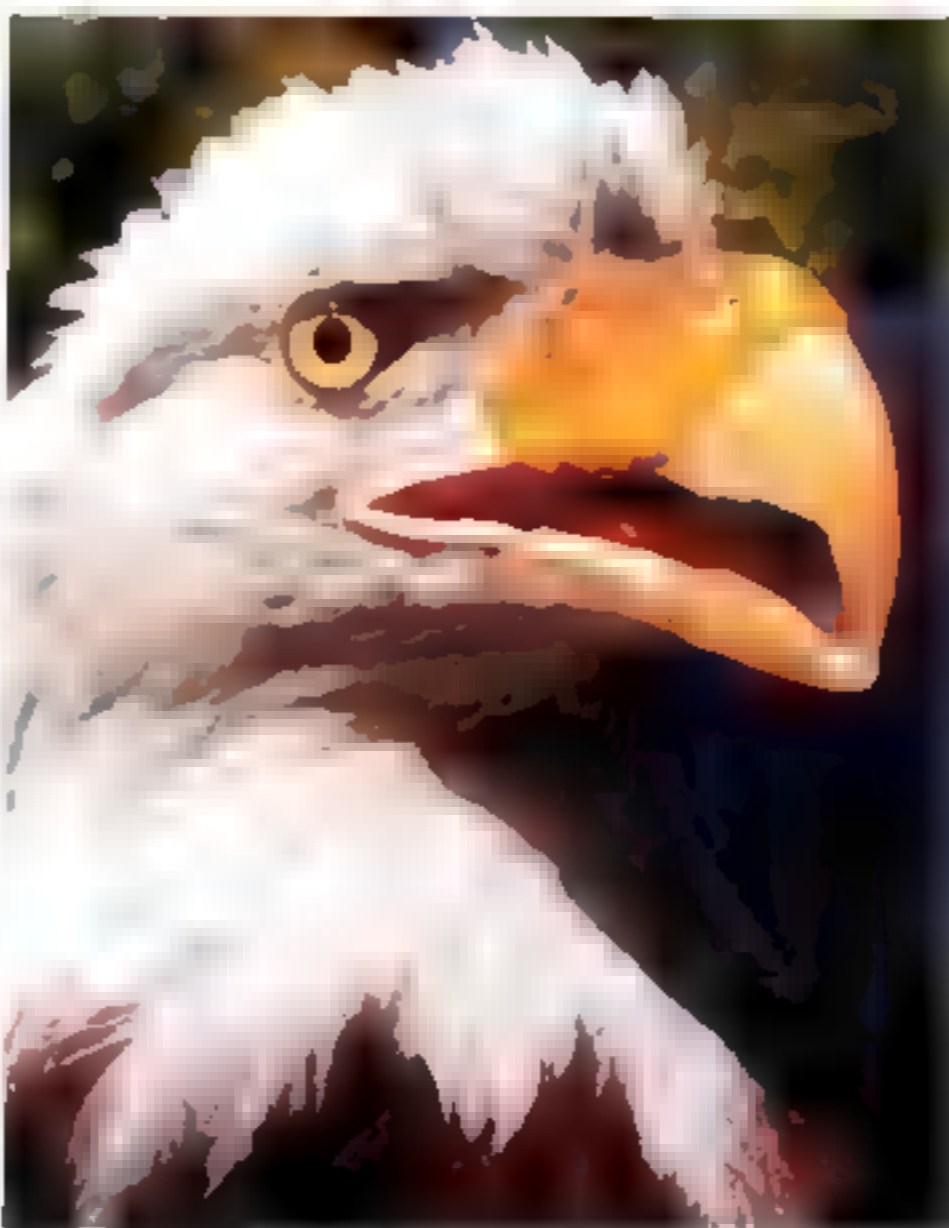
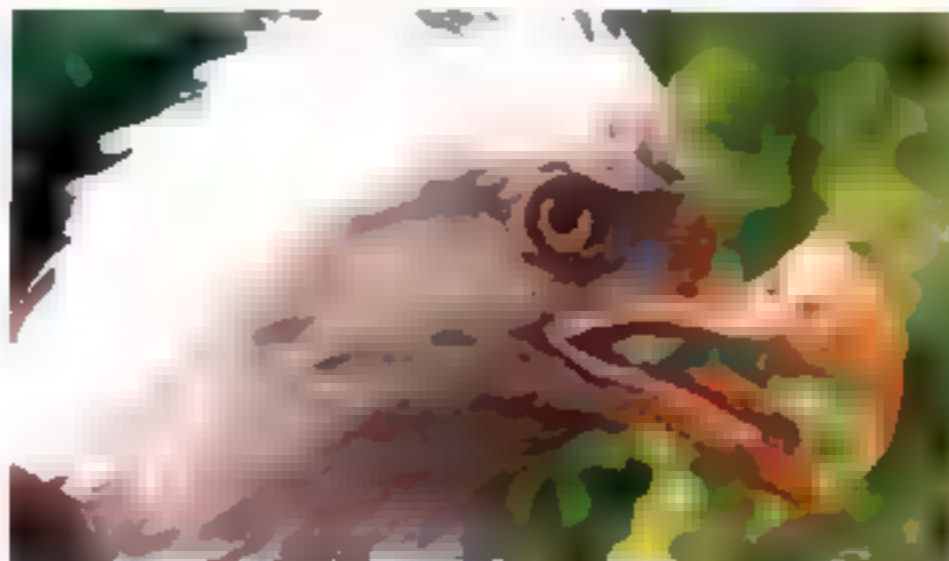
Brian Andrews, a dentist in Nanaimo on Canada's Vancouver Island, has made many sets of false teeth.

But a false beak for a wounded bald eagle?

That was the challenge he faced when he offered to repair the beak of an 18-pound male

eagle shot by a high-powered rifle, leaving only the lower beak and the tip of the upper beak (top right). Authorities don't know who shot the bird or why.

Workers at the North Island Wildlife Recovery Centre in Parksville nursed the bird back



TOM MACDOUGALL, VANCOUVER SUN (BOTH)

to health, then advertised for dental help. Andrews volunteered his services, free of charge. “Fortunately, your magazine came out with that beautiful picture of the eagle on the cover,” he says. The dentist used Norbert Rosing's

photograph as a model in creating successively better versions of an artificial beak that can be removed regularly for cleaning (the prototype is pictured here). “Now we're using a model with plastic next to the forehead and metal on the upper portion of the beak, almost including the tip and the lips,” he explains. “It fits over the beak, on a hinge mechanism attached with a screw.”

Eagle and new beak are doing just fine. “He's ripping herring apart with great abandon,” Andrews reports.

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VIAGRA
(sildenafil citrate) tablets

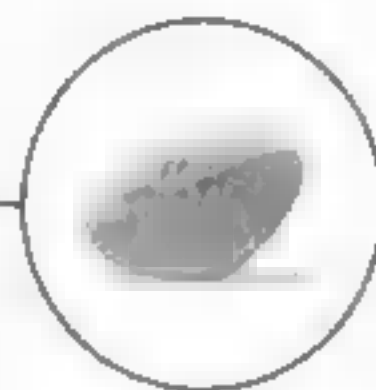
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VIAGRA is indicated for the treatment of erectile dysfunction. Remember that no medicine is for everyone. If you use nitrate drugs, often used to control chest pain (also known as angina), don't take VIAGRA. This combination could cause your blood pressure to drop to an unsafe or life-threatening level.

Discuss your general health status with your doctor to ensure that you are healthy enough to engage in sexual activity. If you experience chest pain, nausea, or any other discomforts during sex or an erection that lasts longer than 4 hours, seek immediate medical help. The most common side effects of VIAGRA are headache, facial flushing, and upset stomach. Less commonly bluish vision, blurred vision, or sensitivity to light may briefly occur.

Please see patient summary of information for VIAGRA (25-mg, 50-mg, 100-mg) tablets on the following page.

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PATIENT SUMMARY OF INFORMATION ABOUT

VIAGRA®
(sildenafil citrate) tablets

This summary contains important information about VIAGRA®. It is not meant to take the place of your doctor's instructions. Read this information carefully before you start taking VIAGRA. Ask your doctor or pharmacist if you do not understand any of this information or if you want to know more about VIAGRA.

This medicine can help many men when it is used as prescribed by their doctors. However, VIAGRA is not for everyone. It is intended for use only by men who have a condition called erectile dysfunction. **VIAGRA must never be used by men who are taking medicines that contain nitrates of any kind, at any time. This includes nitroglycerin. If you take VIAGRA with any nitrate medicine your blood pressure could suddenly drop to an unsafe or life threatening level.**

What is VIAGRA?

VIAGRA is a pill used to treat erectile dysfunction (impotence) in men. It can help many men who have erectile dysfunction get and keep an erection when they become sexually excited (stimulated).

You will not get an erection just by taking this medicine. VIAGRA helps a man with erectile dysfunction get an erection only when he is sexually excited.

How Sex Affects the Body

When a man is sexually excited, the penis rapidly fills with more blood than usual. The penis then expands and hardens. This is called an erection. After the man is done having sex, this extra blood flows out of the penis back into the body. The erection goes away. If an erection lasts for a long time (more than 6 hours), it can permanently damage your penis. You should call a doctor immediately if you ever have a prolonged erection that lasts more than 4 hours.

Some conditions and medicines interfere with this natural erection process. The penis cannot fill with enough blood. The man cannot have an erection. This is called erectile dysfunction if it becomes a frequent problem.

During sex, your heart works harder. Therefore sexual activity may not be advisable for people who have heart problems. Before you start any treatment for erectile dysfunction, ask your doctor if your heart is healthy enough to handle the extra strain of having sex. If you have chest pains, dizziness, or fainting during sex, stop having sex and immediately tell your doctor you have had this problem.

How VIAGRA Works

VIAGRA enables many men with erectile dysfunction to respond to sexual stimulation. When a man is sexually excited, VIAGRA helps the penis fill with enough blood to cause an erection. After sex is over, the erection goes away.

VIAGRA Is Not for Everyone

As noted above (*How Sex Affects the Body*), ask your doctor if your heart is healthy enough for sexual activity.

If you take any medicines that contain nitrates—either regularly or as needed—you should never take VIAGRA. If you take VIAGRA with any nitrate medicine or recreational drug containing nitrates, your blood pressure could suddenly drop to an unsafe level. You could get dizzy, faint, or even have a heart attack or stroke. Nitrates are found in many prescription medicines that are used to treat angina (chest pain due to heart disease) such as:

- nitroglycerin (sprays, ointments, skin patches or pastes, and tablets that are swallowed or dissolved in the mouth)
- isosorbide mononitrate and isosorbide dinitrate (tablets that are swallowed, chewed, or dissolved in the mouth)

Nitrates are also found in recreational drugs such as amyl nitrate or nitrite ("poppers"). If you are not sure if any of your medicines contain nitrates, or if you do not understand what nitrates are, ask your doctor or pharmacist.

VIAGRA is only for patients with erectile dysfunction. VIAGRA is not for newborns, children, or women. Do not let anyone else take your VIAGRA. VIAGRA must be used only under a doctor's supervision.

What VIAGRA Does Not Do

- VIAGRA does not cure erectile dysfunction. It is a treatment for erectile dysfunction.
- VIAGRA does not protect you or your partner from getting sexually transmitted diseases, including HIV—the virus that causes AIDS.
- VIAGRA is not a hormone or an aphrodisiac.

What To Tell Your Doctor Before You Begin VIAGRA

Only your doctor can decide if VIAGRA is right for you. VIAGRA can cause mild, temporary lowering of your blood pressure. You will need to have a thorough medical exam to diagnose your erectile dysfunction and to find out if you can safely take VIAGRA alone or with your other medicines. Your doctor should determine if your heart is healthy enough to handle the extra strain of having sex.

Be sure to tell your doctor if you:

- have ever had any heart problems (e.g., angina, chest pain, heart failure, irregular heart beats, or heart attack)
- have ever had a stroke
- have low or high blood pressure

- have a rare inherited eye disease called retinitis pigmentosa
- have ever had any kidney problems
- have ever had any liver problems
- have ever had any blood problems, including sickle cell anemia or leukemia
- are allergic to sildenafil or any of the other ingredients of VIAGRA tablets
- have a deformed penis, Peyronie's disease, or ever had an erection that lasted more than 4 hours
- have stomach ulcers or any types of bleeding problems
- are taking any other medicines

VIAGRA and Other Medicines

Some medicines can change the way VIAGRA works. Tell your doctor about **any medicines** you are taking. Do not start or stop taking any medicines before checking with your doctor or pharmacist. This includes prescription and nonprescription medicines and remedies. Remember, VIAGRA should never be used with medicines that contain nitrates (see *VIAGRA Is Not for Everyone*). If you are taking a protease inhibitor, your dose may be adjusted (please see *Finding the Right Dose for You*). VIAGRA should not be used with any other medical treatments that cause erections. These treatments include pills, medicines that are injected or inserted into the penis, implants or vacuum pumps.

Finding the Right Dose for You

VIAGRA comes in different doses (25 mg, 50 mg and 100 mg). If you do not get the results you expect, talk with your doctor. You and your doctor can determine the dose that works best for you.

- Do not take more VIAGRA than your doctor prescribes.
- If you think you need a larger dose of VIAGRA, check with your doctor.
- VIAGRA should not be taken more than once a day.

If you are older than age 65, or have serious liver or kidney problems, your doctor may start you at the lowest dose (25 mg) of VIAGRA. If you are taking protease inhibitors, such as for the treatment of HIV, your doctor may recommend a 25 mg dose and may limit you to a maximum single dose of 25 mg of VIAGRA in a 48 hour period.

How To Take VIAGRA

Take VIAGRA about one hour before you plan to have sex. Beginning about 30 minutes and for up to 4 hours, VIAGRA can help you get an erection if you are sexually excited. If you take VIAGRA after a high-fat meal (such as a cheeseburger and french fries), the medicine may take a little longer to start working. VIAGRA can help you get an erection when you are sexually excited. You will not get an erection just by taking the pill.

Possible Side Effects

Like all medicines, VIAGRA can cause some side effects. These effects are usually mild to moderate and usually don't last longer than a few hours. Some of these side effects are more likely to occur with higher doses. The most common side effects of VIAGRA are headache, flushing of the face, and upset stomach. Less common side effects that may occur are temporary changes in color vision (such as trouble telling the difference between blue and green objects or having a blue color tinge to them), eyes being more sensitive to light, or blurred vision.

In some instances, men have reported an erection that lasts many hours. You should call a doctor immediately if you ever have an erection that lasts more than 4 hours. If not treated right away, permanent damage to your penis could occur (see *How Sex Affects the Body*).

Heart attack, stroke, irregular heart beats, and death have been reported rarely in men taking VIAGRA. Most, but not all, of these men had heart problems before taking this medicine. It is not possible to determine whether these events were directly related to VIAGRA.

VIAGRA may cause other side effects besides those listed on this sheet. If you want more information or develop any side effects or symptoms you are concerned about, call your doctor.

Accidental Overdose

In case of accidental overdose, call your doctor right away.

Storing VIAGRA

Keep VIAGRA out of the reach of children. Keep VIAGRA in its original container. Store at room temperature 59°-86°F (15°-30°C).

For More Information on VIAGRA

VIAGRA is a prescription medicine used to treat erectile dysfunction. Only your doctor can decide if it is right for you. This sheet is only a summary. If you have any questions or want more information about VIAGRA, talk with your doctor or pharmacist, visit www.viagra.com, or call 1-888-4VIAGRA.

23-5515-00-4

June 1999

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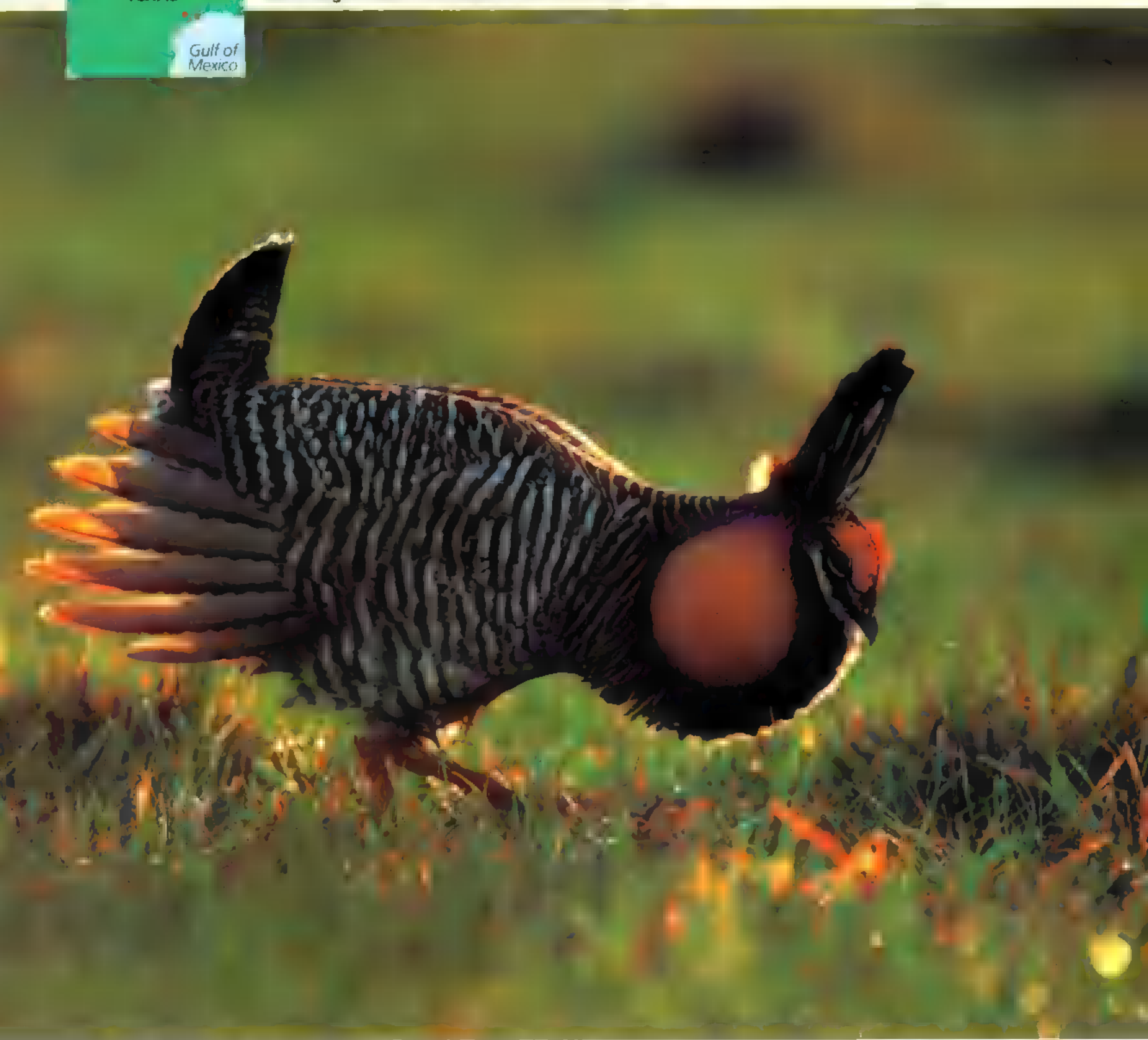


Attwater's Prairie-Chicken (*Tympanuchus cupido attwateri*)

Size: Length, 42-46 cm **Weight:** 700-900 g

Habitat: Confined to two reserves, totaling only 12,400 acres, in what remains of the coastal prairie of Texas

Surviving number: Estimated at fewer than 50



Photographed by Joel Sartore

WILDLIFE AS CANON SEES IT

Boo-oom! Attwater's prairie-chicken certainly knows how to get attention. Puffing up air sacs on either side of its neck, the male looses a boom that can be heard nearly a kilometer away. It's all part of a springtime courtship display, complete with rigid tail and neck feathers, strutting, bowing and a blur of foot stomping. Tribal dances of America's Plains Indians were inspired by this display. The ground-dwelling grouse has attracted much

unwanted attention: over-hunted when plentiful, it is now prey to predators in a greatly straitened habitat. With populations plummeting from one million a century ago to fewer than 50, it may well go the way of the Dodo.

As an active, committed global corporation, we join worldwide efforts to promote awareness of endangered species. Just one way we are working to make the world a better place—today and tomorrow.

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National Geographic TV



ELIYAH SHADIMANI, WILDCHEF / ELIYAH SHADIMANI

NATIONAL GEOGRAPHIC
EXPLORER, MSNBC

Hunting Dogs of Arabia

Talk about pedigree: The saluki, a long-legged hunting hound, may have appeared as far back as 6000 B.C. Considered sacred by Egyptians, it has chased gazelles for Bedouins for perhaps a thousand years. Filmmakers Dereck and Beverly Joubert journeyed across Arabia and North Africa to portray the enduring skills of one of the world's oldest breeds of domesticated dog. *Hunting Hounds of Arabia* joins saluki hunts in the desert, and showcases a breeder in the United Arab Emirates (left) who pampers his dogs with milk and honey.

NATIONAL GEOGRAPHIC
CHANNEL

Nature's Nightmares

Vampire bats can terrify people from Mexico to Argentina. But for some researchers, the closer they get to their creepy-floppy subjects the better (in one case, close enough to collect vampire bat saliva for use in a potentially life-saving drug). Follow scientists into a Venezuelan cave in *Spine Chillers: Vampire Bats*, an episode in the Channel's new series, *Nature's Nightmares*.



MICHAEL FODDER, ANIMALS, ANIMALS, EARTH SCENES

National Geographic EXPLORER MSNBC, Sundays, 8 p.m. ET/5 p.m. PT. National Geographic Specials PBS. See local listings. National Geographic Videos, Kids Videos, and DVDs Call 1-800-827-5162. National Geographic Channel Call your cable or satellite provider.

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Introducing the Honda FCX, the first zero-emission fuel-cell car on the road.

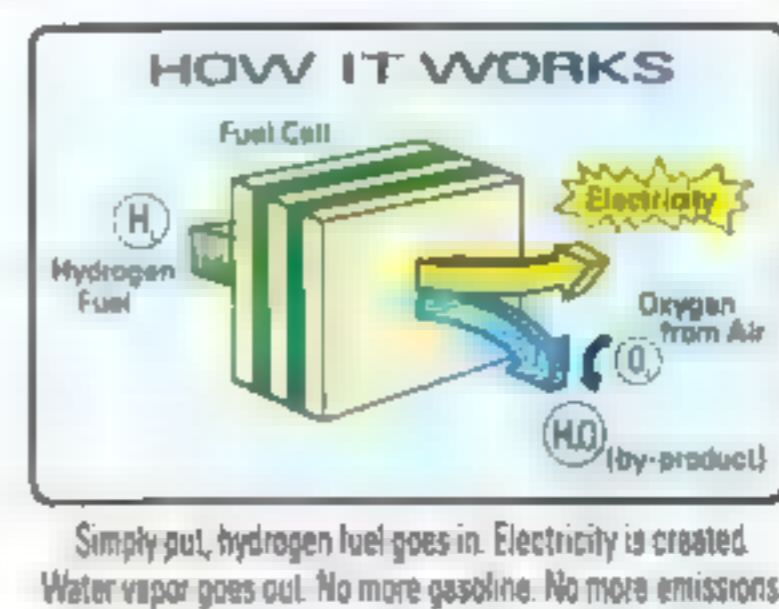


The Honda FCX is the first fuel-cell car to be government-certified for everyday use. Being first is a good feeling. We should know. Honda has been a pioneer of environmental technology from the beginning.

The 1975 Civic CVCC was the first car to meet the emission standards of the Clean Air Act without a catalytic converter. Then came the natural-gas Civic GX. With its near-zero-emission engine, the EPA has called it the cleanest engine on Earth. In 1999, America welcomed the Insight, the first hybrid gas-electric car from Honda. And just this year, the Civic became the first mass-market vehicle to provide a hybrid powertrain option in the United States.

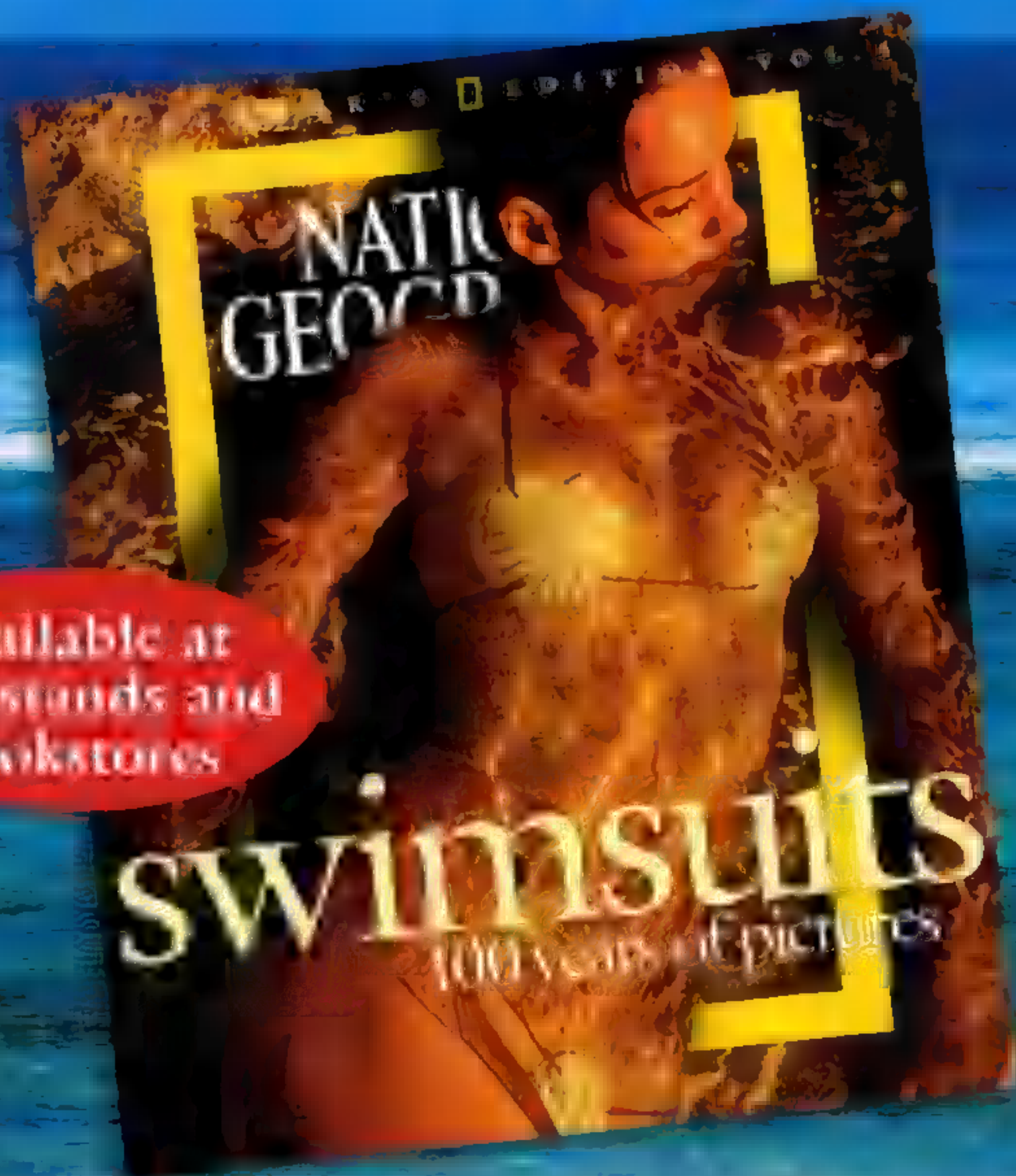
See what we mean? It's a little like tradition. Now, with the stamp of approval from the Environmental Protection Agency and the California Air Resources Board, Honda is delivering a family of new FCX fuel-cell vehicles to its first customer, the City of Los Angeles.

Step by step, Honda's long-standing dream of a zero-emission future may just become a reality. For more information on the new FCX, visit us at honda.com.



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NATIONAL GEOGRAPHIC

Who Knew?

PERCEPTION

Doctor, My Eyes

How we watch TV ads

An unofficial American holiday every January is Super Bowl Sunday, when a bazillion people congregate in private homes and bars to eat potato chips and watch TV commercials. There's also a football game.

Given that tens of millions of dollars are spent to make and air the ads, you figure at least a few million more might be devoted to figuring out how viewers perceive them. Sure enough, researchers have spent decades watching people watching ads. Of particular interest: what we do with our eyes.

"Our eyes are very busy. They're continuously scanning the visual field in front of them," says Moshe Eizenman of the University of Toronto, the inventor of an eye-tracking device.

Research shows that our gaze zooms in on moving objects, such as the lips of a speaking person. Our eyes are drawn to sharp edges and contrasting colors. That's why commercials often show a colorful product against a white background, and why luxury sedans are constantly hurtling along mountain roads.

A good ad should "encourage a natural visual scanning pattern," reports Eizenman, and his work suggests that may not happen if an ad makes the viewer think too much. He studied the eye movements of people driving cars while talking on cell phones. When test subjects were asked, over

their phones, to add two two-digit numbers, they suddenly scanned less of their environment. (Ever find yourself squinting when someone gives you a math problem?)

But can a commercial really make you more likely to choose one product over dozens of brightly packaged competitors on a supermarket shelf?

Chris Janiszewski, professor of marketing at the University of Florida, did a study some years ago on a Mountain Dew commercial. The ad featured Dew-drinking young people surfing river rapids. This frenetic scene was followed by an image of a Mountain Dew can. After showing the commercial to a group of test subjects, Janiszewski then rearranged the ad for a different group. This time he showed the can first, then the surfing. Finally he had both groups view photos of four different soda brands sitting on a shelf while training infrared lights on the subjects' pupils. The second group—the ones who saw the can, then the surfing—looked at the Mountain Dew more quickly. Janiszewski concluded that advertisers can better "condition" viewers if they show the product first.

So far this research is of more interest to academics than to Madison Avenue. "Advertising people aren't engineers," notes Janiszewski. "They're usually liberal arts people."

Maybe someday the Comp Lit majors will be replaced by eye-trackers who will gain total mastery over our minds—but what can you Dew about it?

—Joel Achenbach

WASHINGTON POST STAFF WRITER

IT MATTERS

How many brands of beer can you name?

A lot of schoolkids can name more beers than they can U.S. Presidents. A survey by the Center for Science in the Public Interest revealed that 8-to-12-year-olds know booze better than history. Of course Millard Fillmore and Benjamin Harrison never had Budweiser's talking lizards or a buxom St. Pauli Girl to boost their name recognition. Each year more than a billion dollars of advertising promotes alcohol consumption. It matters that parents and policymakers take that advertising—and its power to shape perception and influence behavior—seriously. The National Longitudinal Alcohol Epidemiologic Survey found that nearly half those who start drinking before they're 13 develop alcohol abuse or dependence at some point in their lives.

—Lynne Warren

WEBSITE EXCLUSIVE

Learn more about the science behind ads and find links to Joel Achenbach's work at nationalgeographic.com/ngm/resources/0302.



Galaxy Hunters

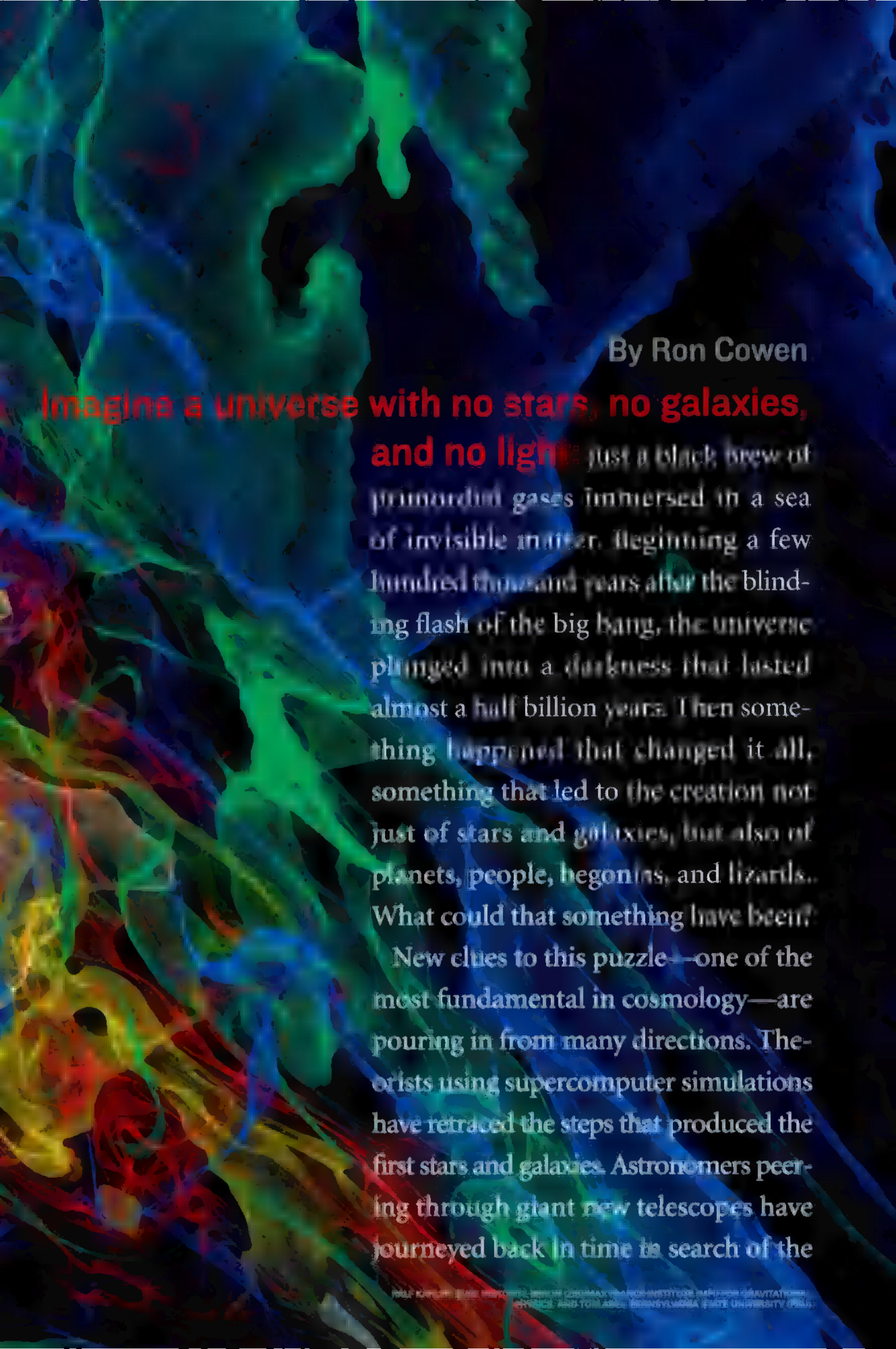
The search for cosmic dawn



The backyard sky never looked like this: Some 200,000 galaxies whirl through space in a computer-generated model using data from the Sloan Digital Sky Survey, an ambitious effort to map one-quarter of the cosmos. Based on images from the Apache Point Observatory in New Mexico, the model marks the locations of nearby galaxies with representative pictures, greatly magnified. Beyond lie 100 billion more galaxies, each with many billions of stars. Where did all the material come from that coalesced into galaxies? Aided by powerful telescopes and computers, scientists are closing ever closer to answers.



TUNING IN: The hiss of TV static denotes remnant radiation that still lingers from the big bang 14.3 billion years ago. Some 100 million years after that explosive dawn of the universe, a microgalaxy was born. With filaments heaved to density levels, a computer simulation shows the outer shell of the microgalaxy in green. Deep inside this turbulent cloud of hydrogen and helium, a dense core forms. Under the pull of gravity it will collapse to become a fiery sun.

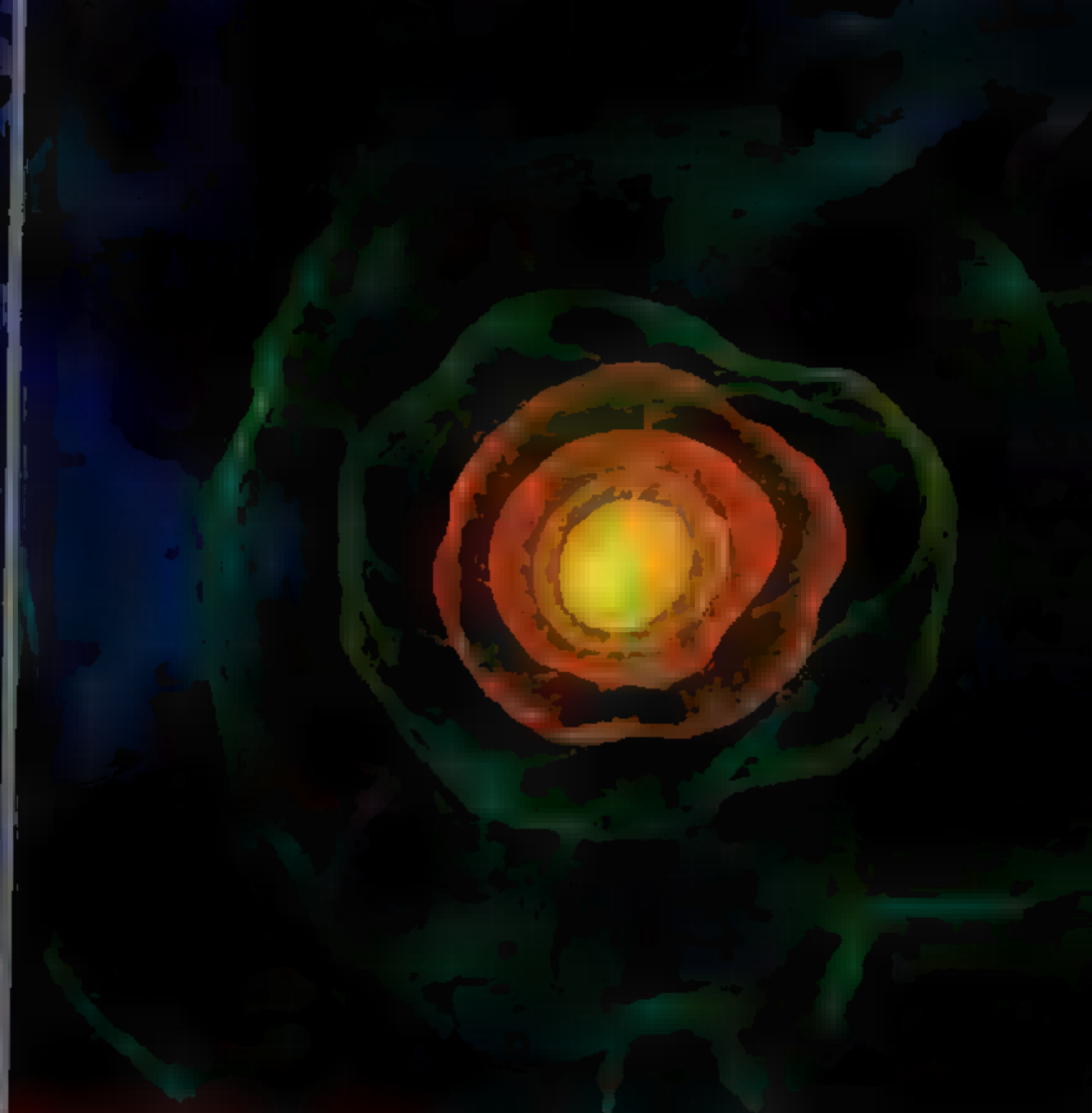
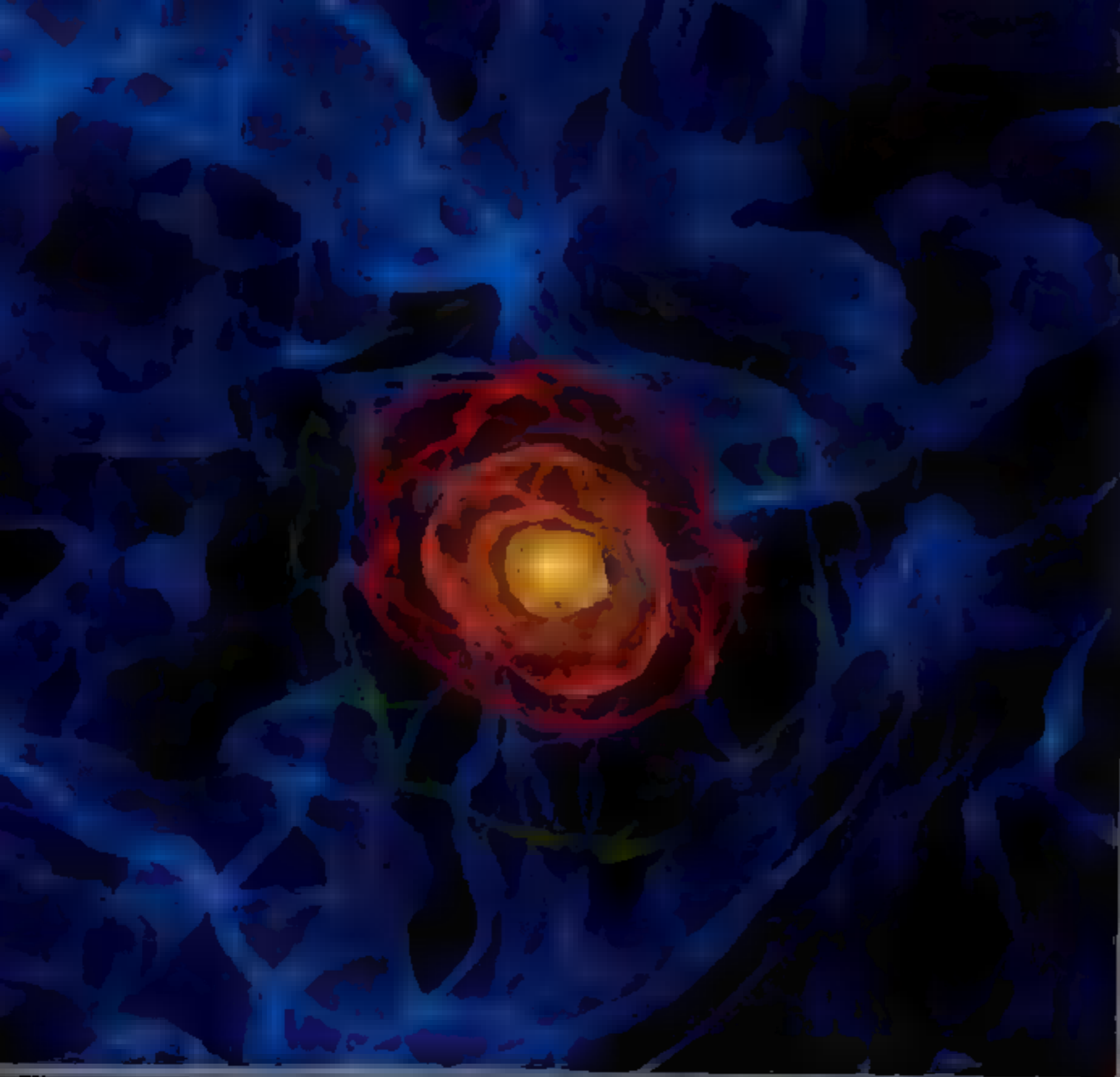


By Ron Cowen

Imagine a universe with no stars, no galaxies, and no light:

just a black brew of primordial gases immersed in a sea of invisible matter. Beginning a few hundred thousand years after the blinding flash of the big bang, the universe plunged into a darkness that lasted almost a half billion years. Then something happened that changed it all, something that led to the creation not just of stars and galaxies, but also of planets, people, begonias, and lizards. What could that something have been?

New clues to this puzzle—one of the most fundamental in cosmology—are pouring in from many directions. Theorists using supercomputer simulations have retraced the steps that produced the first stars and galaxies. Astronomers peering through giant new telescopes have journeyed back in time to search of the

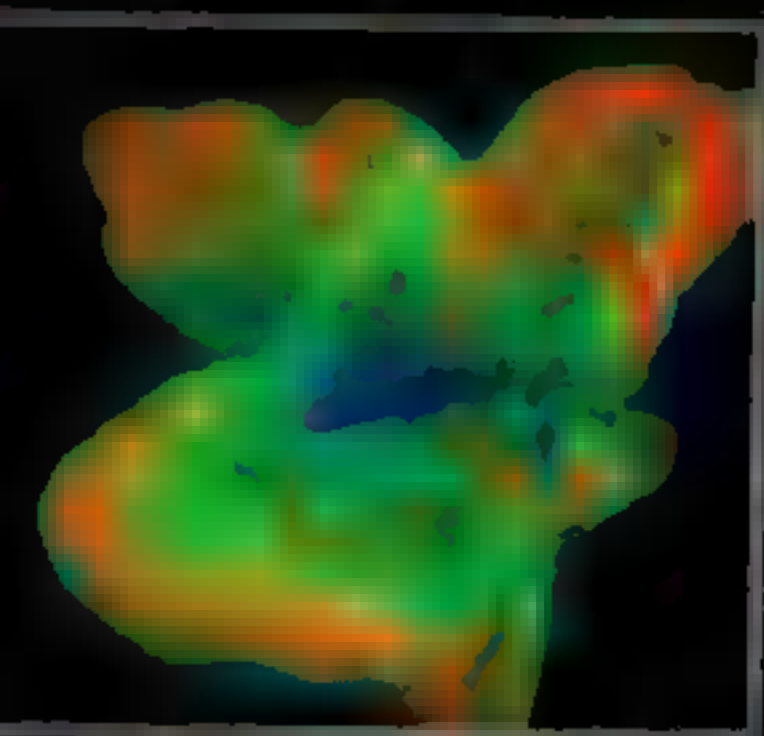


The first star was born about 14 billion years ago, Abel believes, in a universe

GIGANTIC AND LUMINOUS, the earliest star formed like a pearl inside shells of swirling gas, according to a simulation by Tom Abel, an astrophysicist at Pennsylvania State University. Zooming deeper and deeper inside a microgalaxy one millionth the mass of the Milky Way, images (above) unveil a protostar of hydrogen and helium (right) with a mass that will swell up to a hundred times greater than our sun's. During a process that took about a million years, the gas started to cool and clump together, finally collapsing the core. That collapse triggered the nuclear fusion of hydrogen atoms—and the first star blazed into existence. "These stars marked

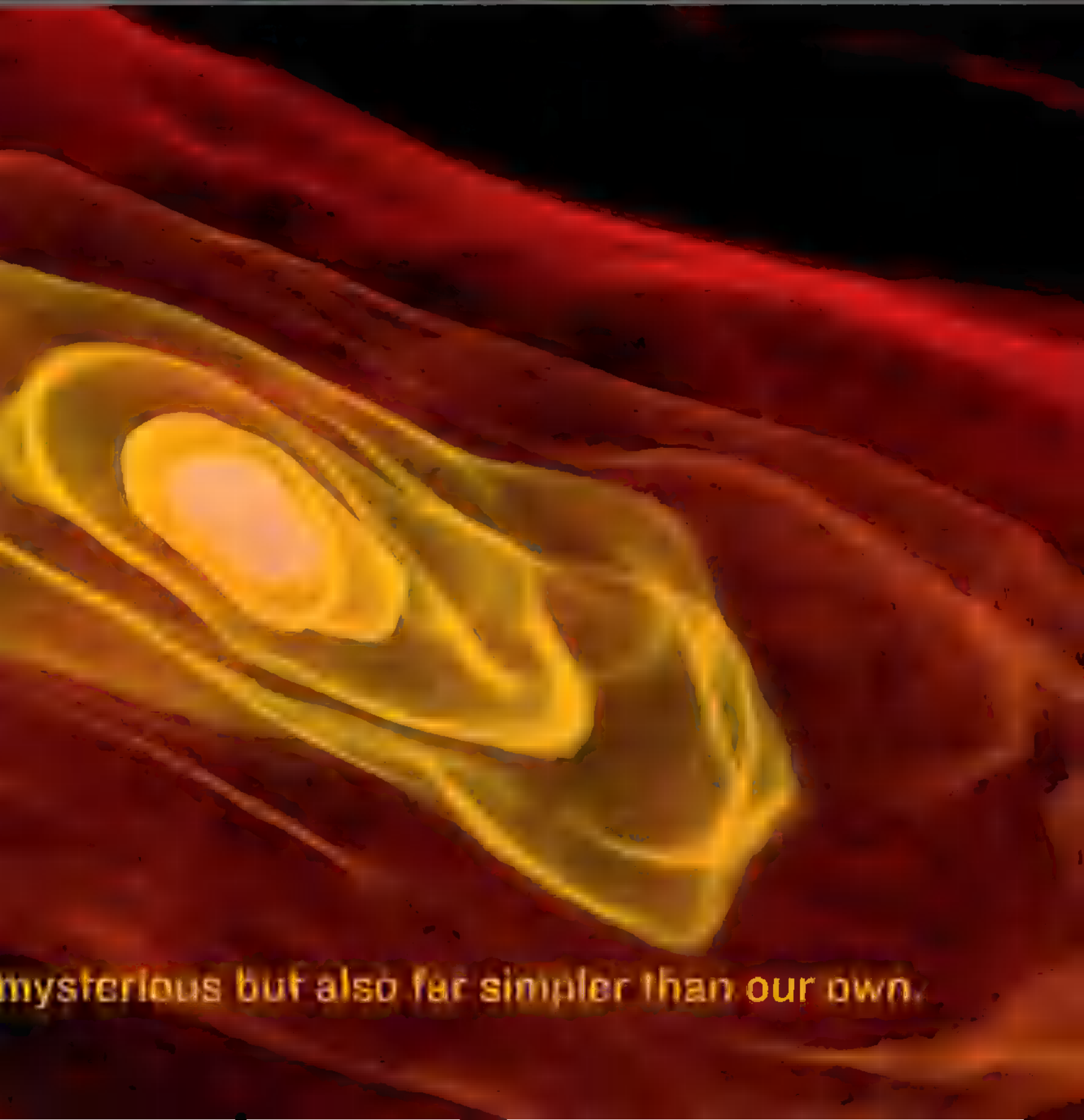
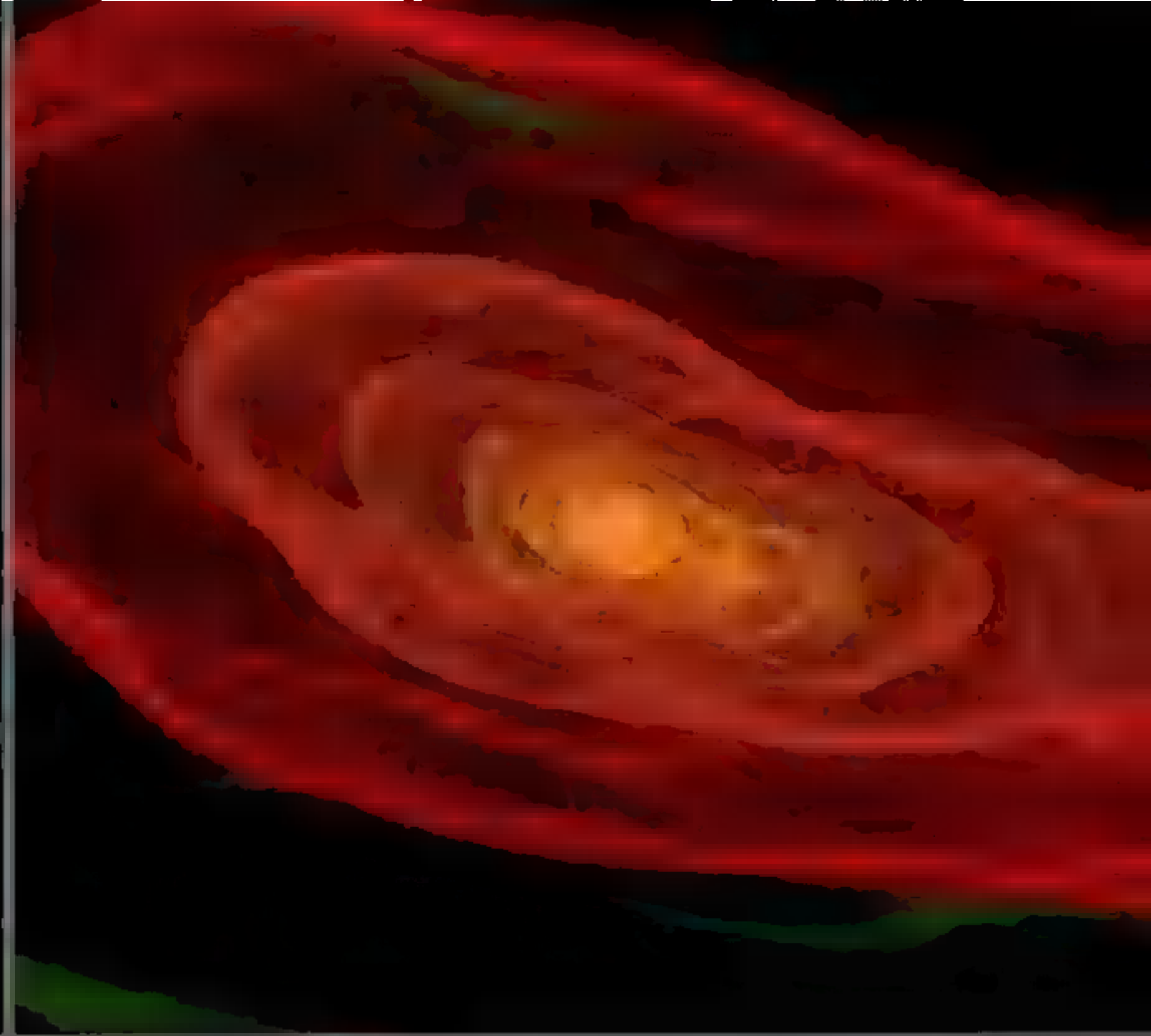
the end of the Dark Ages in the universe," says Abel. The first stars had short lives. Exhausting their fuel within a few million years, they died in supernova explosions

(above), which flung into space new heavier elements such as carbon and oxygen—the seeds of future stars, planets, and life.



that was more

that was more



mysterious but also far simpler than our own.

first galaxies. Researchers studying images from the Hubble Space Telescope have discovered the breathtaking diversity of the galaxies that surround us today—from giant pinwheels blazing with the blue light of newborn stars, to misshapen footballs glowing with the ruddy hue of stars born billions of years ago, to tattered galaxies trailing long streamers of stars torn out by collisions with intruder galaxies.

Less than a century ago astronomers knew only about our own galaxy, the Milky Way, which they believed held about 100 million stars. Then observers discovered that some of the fuzzy blobs in the sky weren't in our own galaxy, but were galaxies in their own right—collections of stars, gas, and dust bound together by gravity. Today we know that the Milky Way contains more than 100 billion stars and that there are some 100 billion galaxies in the universe, each harboring an enormous number of stars.

Our view of the universe is changing completely, says cosmologist Carlos Frenk of the University of Durham in England, and it's largely because of our new understanding of galaxy formation: "It's no exaggeration to say that we're going through a period of change analogous to the Copernican revolution."

ONE OF THE NEW cosmologists, Tom Abel of Pennsylvania State University, thinks he has figured out how the first star was born. One afternoon last April he sat by a hotel pool in Cozumel, Mexico, oblivious to the squawking blackbirds and the whir of the poolside blender kept busy making piña coladas. He was staring intently

past few years, together with his colleagues Michael L. Norman of the University of California, San Diego, and Greg L. Bryan of Oxford University, Abel has created supercomputer simulations that show how stars were formed from these gases.

The first step, according to the simulations, was when gravity gathered gases into diffuse clouds. As the gases cooled, they coalesced at the center of each cloud into a clump no larger than our sun. The clump collapsed further, while surrounding gas piled on top of it. In this way it grew into a behemoth about 100 times the mass of the sun. Finally, several million years after the entire process began, the intense compression forged a full-fledged star—and there was light.

Elsewhere the same star-forming process had begun in other gas clouds that Abel refers to as microgalaxies—miniature, single-starred versions of today's galaxies. Soon beacons of light from massive stars permeated the darkness. These stars burned brightly and then fizzled after only a few million years, dying in titanic explosions called supernovae. During the brief time these first stars reigned, however, they wrought changes in the universe that had a profound effect on future galaxy formation. They heated surrounding gases and bombarded them with ultraviolet light. And when they exploded, the stars seeded the universe, and the next generation of stars, with the first supply of heavy elements, including the oxygen we breathe.

The explosive demise of these stars may have left behind dense cinders, the first black holes in the universe. Moreover, the supernova explosions may have been accompanied by

The concept of dark matter has been around

at images on his laptop computer—images depicting how star formation could have happened. In a few minutes he would go back inside the hotel to share the images with his colleagues at one of the largest meetings ever devoted to the origin of galaxies.

The first star was born about 14 billion years ago, Abel believes, in a universe that was more mysterious but also far simpler than our own. Smaller and denser than today, the universe was pitch-black and contained mostly hydrogen and helium with a smattering of lithium. During the

flashes of energetic radiation known as gamma-ray bursts that are billions of times brighter than the sun. If so, some of the gamma-ray bursts that have already been detected may actually have come from the first stars.

"It would be the most wonderful thing," said Abel, "if we were so lucky that the first stars that formed were also the brightest."

Abel's presentation in Cozumel was a success. Scientists consider his simulations the most convincing scenario yet for how stars were born. The simulations are based on a mind-blowing



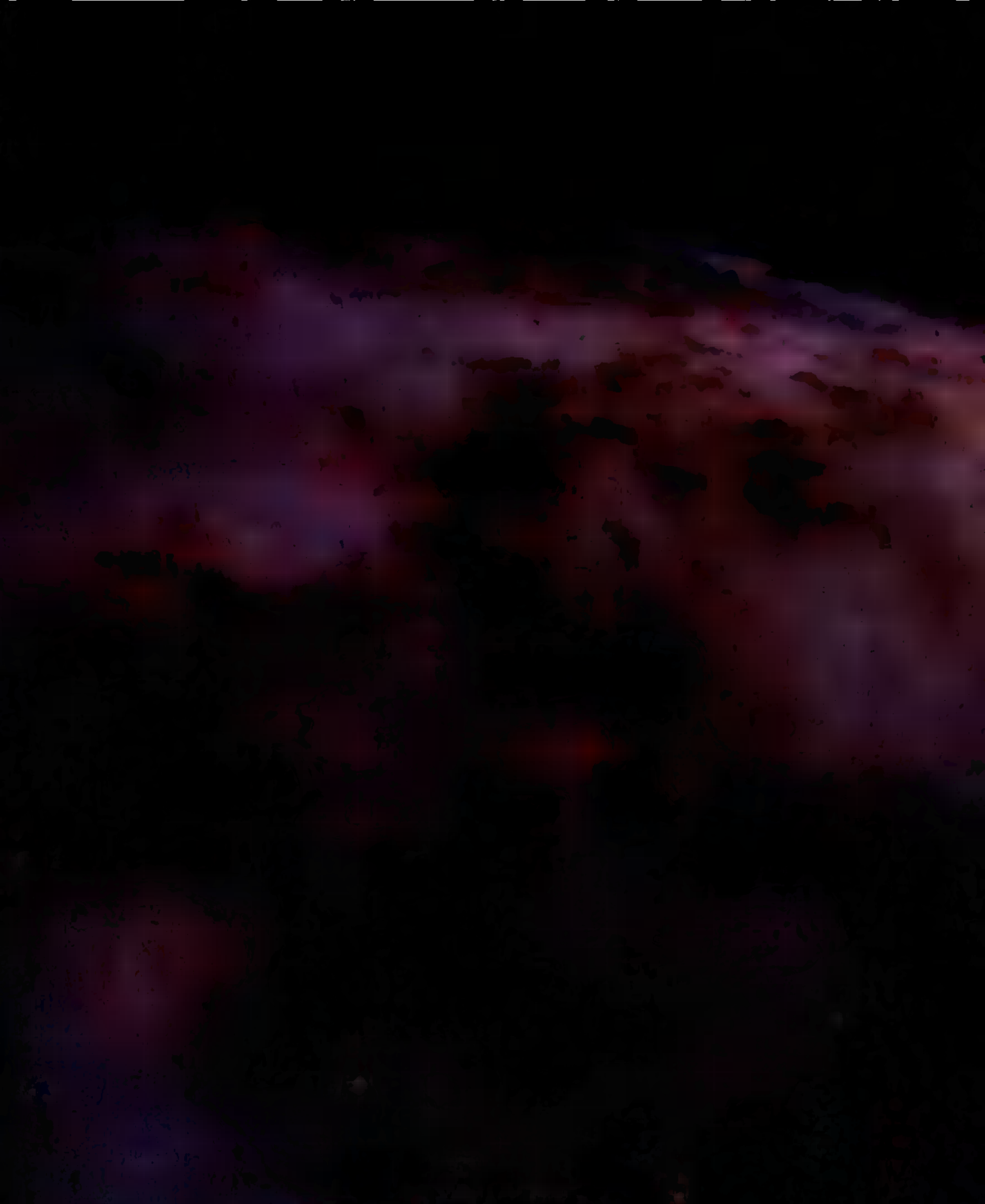
COSMIC REVELATION, ■ photographic negative of the Andromeda galaxy taken in 1923 by astronomer Edwin Hubble became the first proof that galaxies other than the Milky Way existed. The triumphant “VAR!” marked ■ star of variable brightness, valuable ■ ■ ■ measuring tool to show that Andromeda resided far beyond our home galaxy.

for decades. . . . No one wanted to believe
“crazy Fritz” was right.

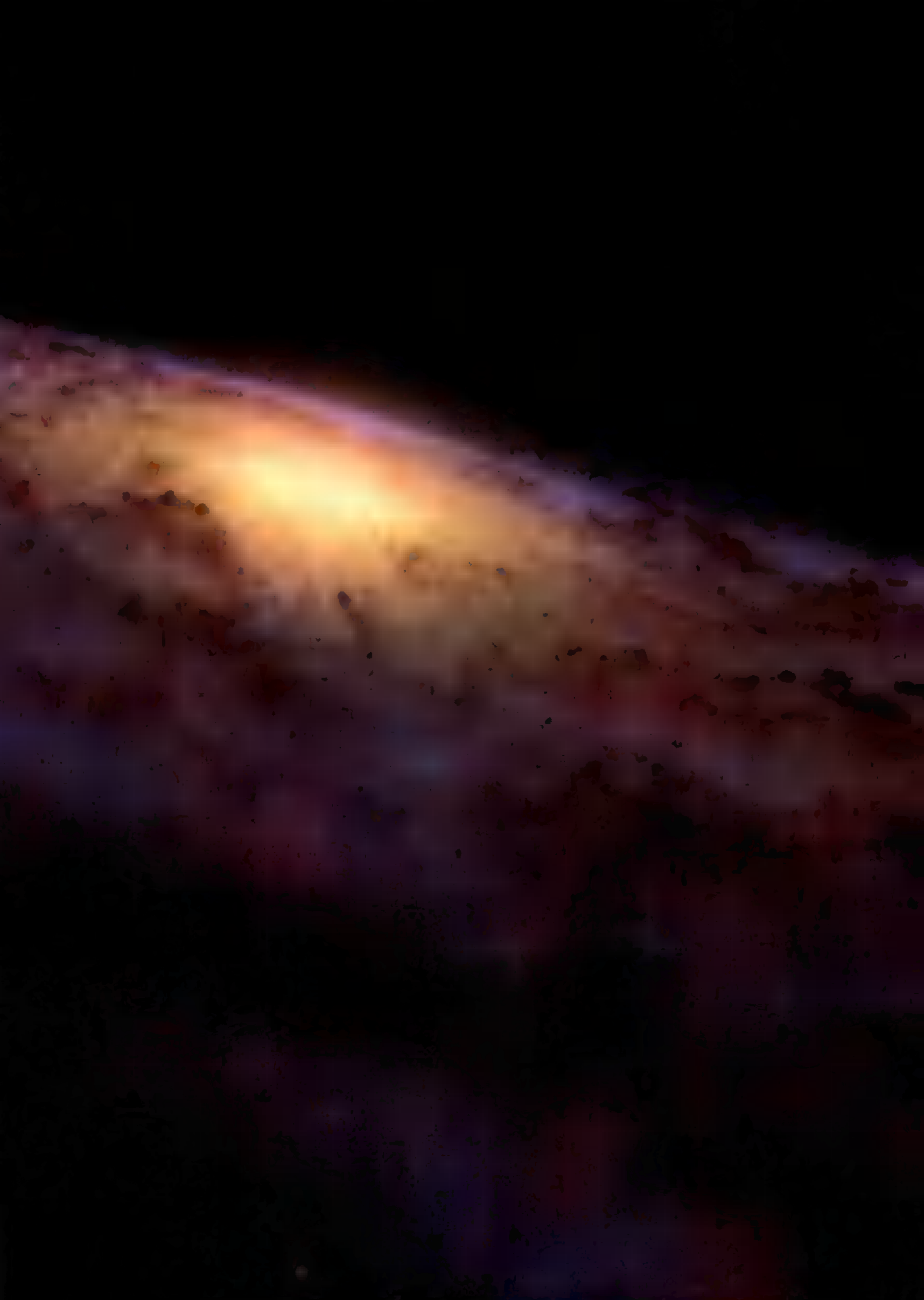
concept: Some kind of mystery material, which can't be seen and has come to be known as dark matter, outweighs all the visible material in the universe by at least nine to one. Galaxies are merely bright flecks on a sea of dark matter. Without the extra tug provided by dark matter, astronomers say, there wouldn't be enough gravity to pull material into galaxy-size clumps or even form the first star.

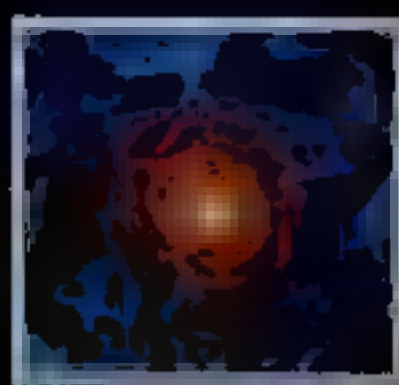
The concept of dark matter has been around

for decades, but cosmologists were slow to embrace it. That might have been because one of the first people to suggest it was a brilliant but abrasive genius named Fritz Zwicky, born in 1898. Zwicky's personality didn't encourage a fan club. He once called his colleagues at the Mount Wilson Observatory “spherical bastards,” because, he said, they were bastards anyway you looked at them. In 1933 Zwicky turned his attention to a nearby (Continued on page 16)



A VIRTUAL MILKY WAY glows from a computer-created vantage point 7,000 light-years above the plane of the star-packed bars. Starting with an image of M83, a comparable galaxy, this 3-D model provides a close-up of our galactic spiral, a look denied to Earth-bound telescopes. Our solar system sits in a far suburb of the Milky Way, halfway out in a region of older and cooler red stars between spiral arms. Most young hot stars are born within the arms.





Simulated microgalaxy formation, 140 million to 400 million years after the Big Bang

Big bang

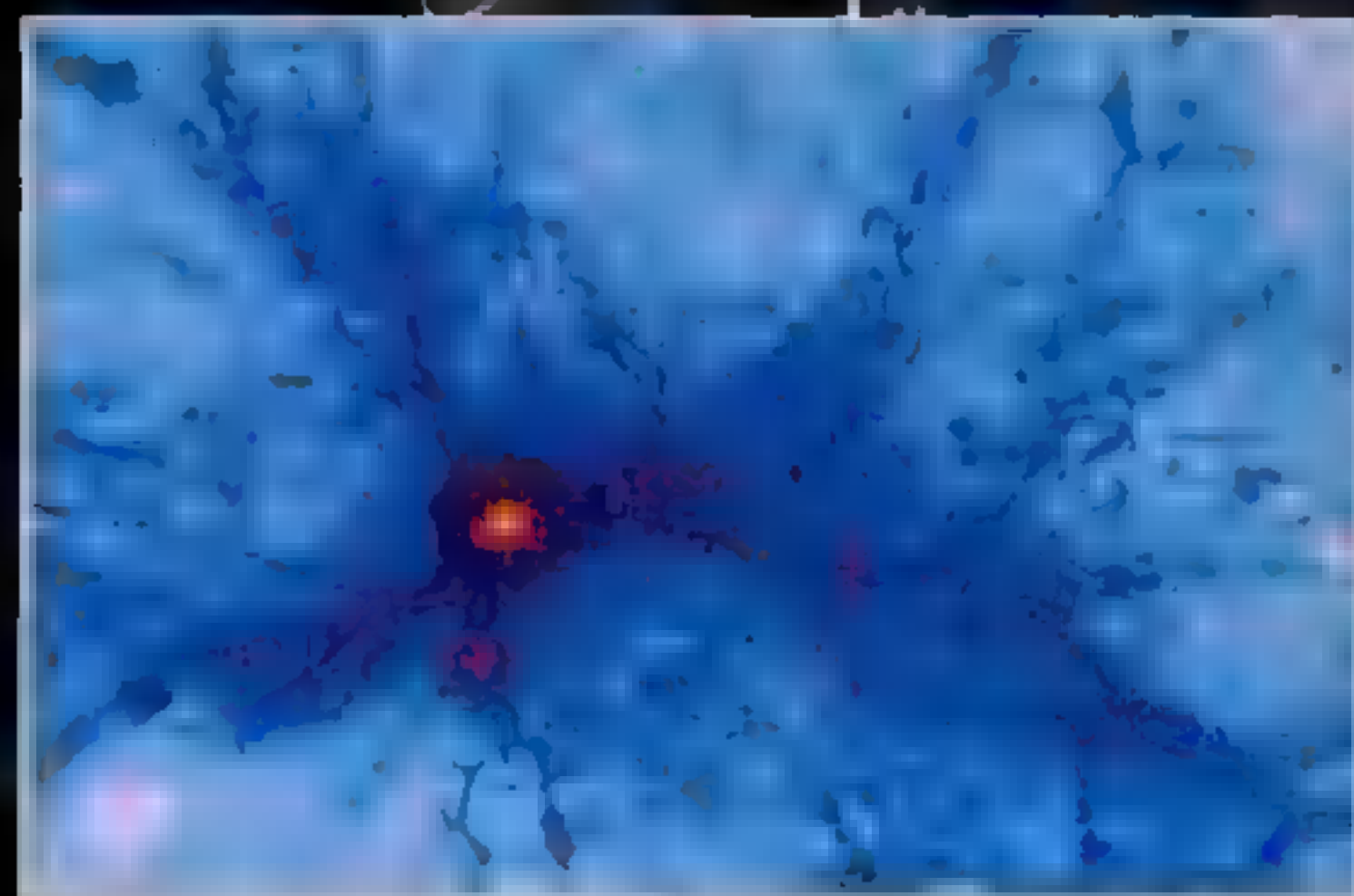
Years in billions

▼ GALAXY FORMATION

To identify the evolution of galaxy structure, a simulation took 100 computer processors 400 million 100-nanosecond steps on each side to show that after a billion years, unseen dark matter formed filaments in force to gather vast clouds of gas. The densest clumps were sustaining the first generation of stars and small galaxies.

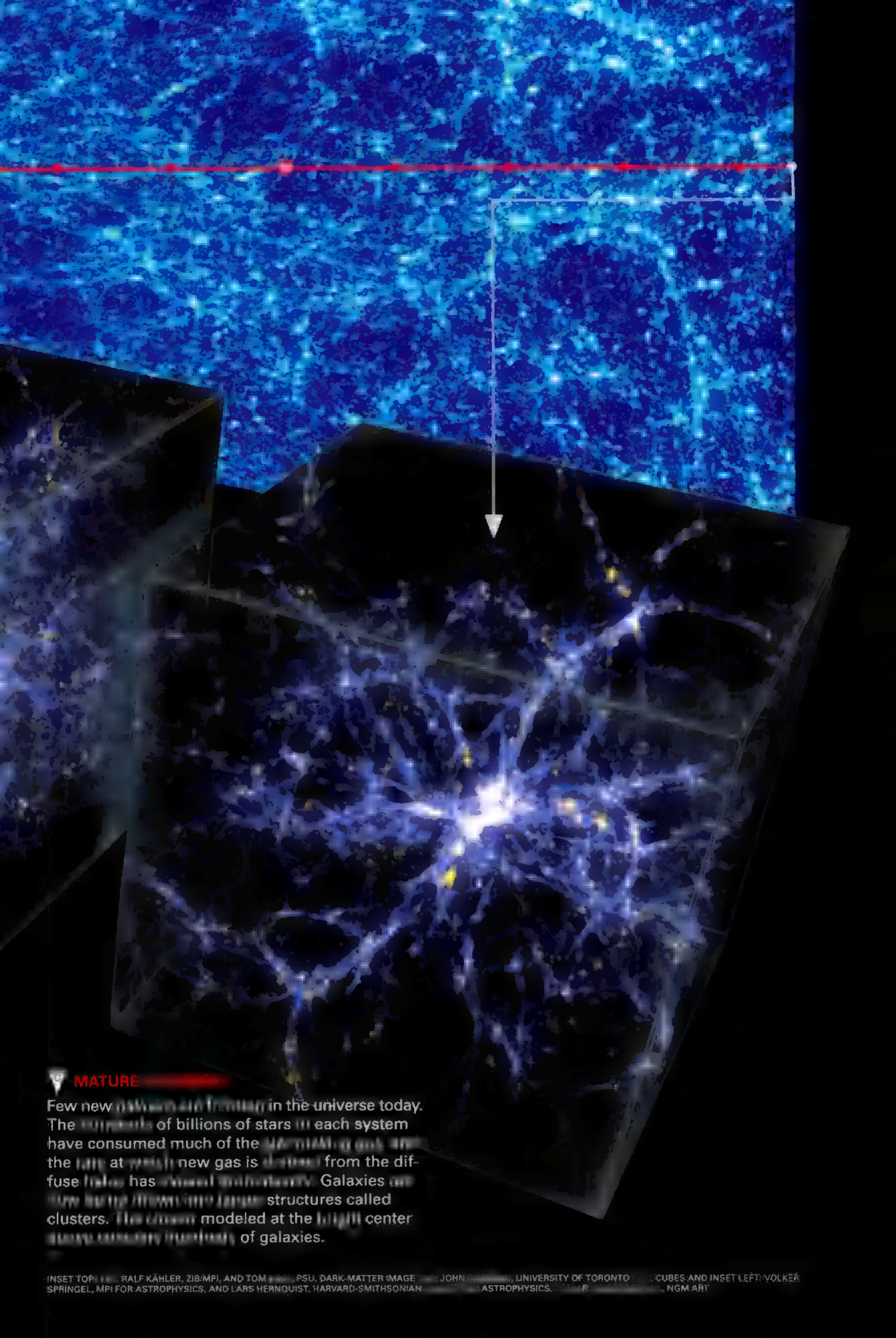
The Invisible Grip of Dark Matter

THE MOST PERSUASIVE theory about the origin of galaxies depends on the behavior of particles no one has ever seen. Known only by its gravitational force, mysterious dark matter pulls ordinary matter into its web, amassing enough gas for galaxies to form. Ordinary matter accounts for only 10 percent of the universe; the rest is dark matter. Cubes depicting three periods in the universe's evolution (above) show the filament-like structure of ordinary matter. A computer-generated image (top) visualizes the distribution of dark matter (white) in an expanding universe over time.



▼ THE GOLDEN AGE

The peak of galaxy birth—the golden age—occurred when the universe was about three billion years old. This inset shows a group of galaxies forming within a halo of gas. During this period galaxies grew larger by drawing in more gas and through frequent collisions with other galaxies.



MATURE

Few new galaxies are forming in the universe today. The hundreds of billions of stars in each system have consumed much of the remaining gas, and the rate at which new gas is drawn from the diffuse filaments has slowed dramatically. Galaxies are now being drawn into larger structures called clusters. The cluster modeled at the bottom center always contains hundreds of galaxies.



“It would be the most wonderful thing,” said

cluster of galaxies, the Coma cluster, and realized it shouldn't exist. Individual galaxies in Coma were zipping around so fast that the gravity exerted by the visible parts of the cluster was too puny to keep Coma intact. But Zwicky had a solution. He proposed that all the visible material in the cluster was a mere fillip. The rest, which he could not see, he dubbed dark matter. No one wanted to believe “crazy Fritz” was right.

Decades later, resistance to Zwicky's ideas began to fade when astronomers found themselves invoking dark matter to explain a host of puzzles. In 1973 Princeton cosmologists Jim Peebles and Jerry Ostriker said the mystery material was necessary to keep spiral galaxies, including our own Milky Way, from falling apart. A few years later, Vera Rubin of the Carnegie Institution of Washington concluded that spiral galaxies she and her colleagues had examined had to be embedded in a halo of dark matter. That was the only way to explain, she said, why stars at the outer edge of the spiral galaxies moved no more slowly than stars at the core.

Dark matter, moreover, answered a key riddle of galaxy formation: how the universe changed from a smooth, hot soup of particles into a jumble of galaxies and galaxy clusters. There had to be some lumps in the first place. By itself, ordinary matter—protons, electrons, and neutrons—couldn't provide those lumps. There wasn't enough of it, and it couldn't begin clumping until the universe had cooled. Dark matter, by contrast, was plentiful and all but impervious to every force but gravity. It could coalesce almost immediately after the universe's birth, giving ordinary matter a foothold to form galaxies, even as cosmic expansion tried to pull them apart.

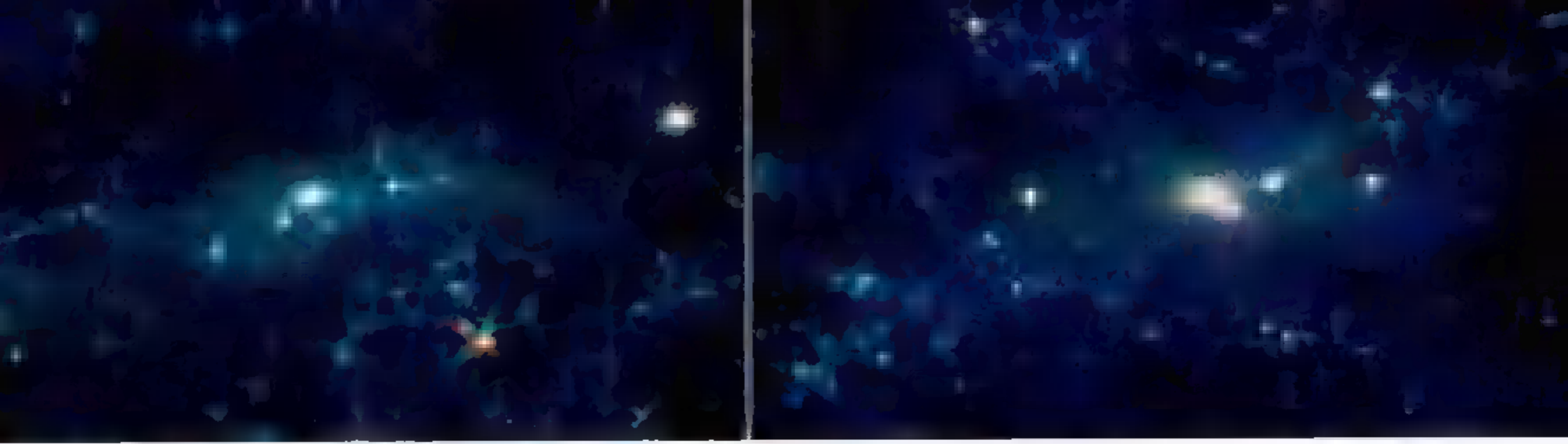
Evidence backing up the lumpy soup theory came in 1992, when a NASA satellite called the Cosmic Background Explorer detected tiny hot

and cold spots in space. This supported the idea that the seeds of galaxy formation—the primordial lumps in the early universe created by dark matter—left tiny temperature variations in the cosmic microwave background, now cooled to a frigid 2.73 degrees above absolute zero. Famed cosmologist Stephen Hawking pronounced the finding the “discovery of the century, if not of all time.”

EDWIN HUBBLE set the stage for today's studies of galaxy formation when he discovered that the Milky Way was not alone. In the predawn hours of October 6, 1923, at the Mount Wilson Observatory in California, he photographed a fuzzy, spiral-shaped clump of stars known as M31, or Andromeda, which most astronomers assumed was part of the Milky Way. He soon realized that within the clump he had found a tiny jewel: a star known as a Cepheid variable. This type of star has a wonderful property: Its brightness waxes and wanes like clockwork, and the longer it takes to vary, the greater the star's intrinsic brightness. That means the star can be used to measure cosmic distances. By comparing the true brightness of the Cepheid in M31 with its brightness as it appears in the sky, Hubble was able to determine the distance between Earth and the star.

He discovered that the star and the cloud, or nebula, in which it resided were a million light-years away—three times the estimated diameter of the entire universe! Clearly this clump of stars resided far beyond the confines of the Milky Way. But if Andromeda was a separate galaxy, then maybe many of the other nebulae in the sky were galaxies as well. The known universe suddenly ballooned in size.

Hubble soon recognized that galaxies come in three varieties. Ellipticals, which converted most



Abel, “if we were so lucky that the first stars that formed were also the brightest.”

of their gas into stars long ago, resemble distorted footballs. Spiral galaxies, including our own Milky Way, account for two-thirds of the known galaxies in the universe. These galaxies have central bulges of old stars, just like an elliptical, but their cores are surrounded by disks containing slender, spiral arms still aglow with newborn stars. Our nearest spiral neighbor, Andromeda, resembles a Frisbee with a fried egg at its center. Finally, irregular galaxies are the plodders, apparently making stars at the same slow rate ever since they were born.

This diversity of galaxies is rooted in violence, according to Julio Navarro of the University of Victoria in British Columbia. Like Abel, Navarro relies on computer simulations to study galaxy evolution, but his work focuses on galaxies later in their life cycles, when they are prone to smash into each other and are chock-full of stars. Recent studies by Navarro and Matthias Steinmetz of the Astrophysical Institute Potsdam in Germany depict how collisions could have altered the appearance of a single galaxy as it made its way through some 12 billion years of cosmic history.

The first galaxy was a disk, Navarro believes, a consequence of the object’s rapid rotation and the pull of gravity. As this disk repeatedly ran into and fused with other baby galaxies, the orbits of its stars became scrambled. The battered disk puffed into a swirling, sparkly ball of gas and stars—an elliptical galaxy. Then, as the galaxy slowly dragged in streamers of gas, the ball became the aging centerpiece of a bigger disk with spiral arms. Another collision erased that structure and created a larger ball. With each collision the galaxy altered its shape, like a lump of clay constantly being resculpted,

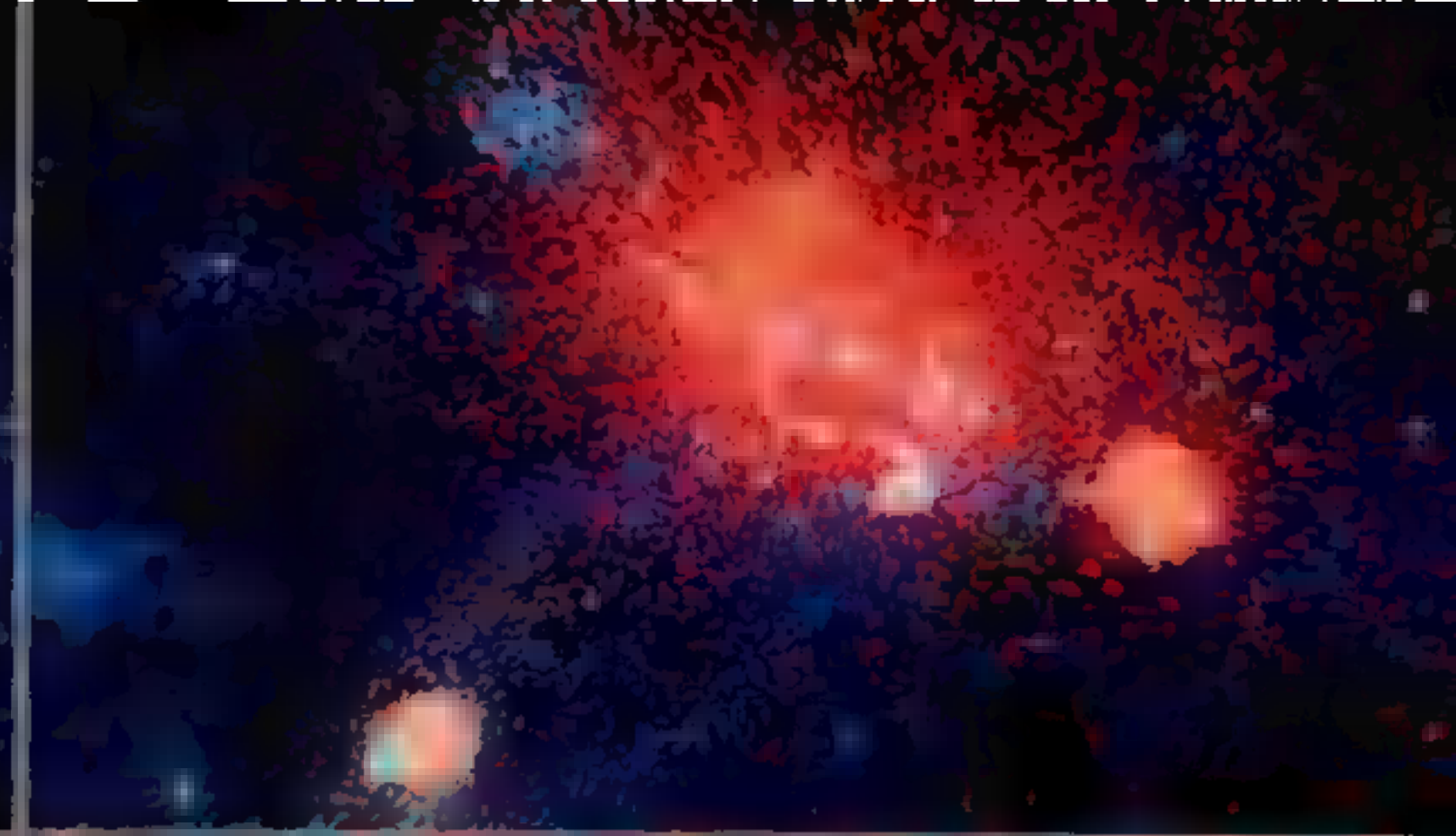
THE “BOTTOM UP” model of galaxy building (sequence above) shows how gas (red) and new stars (white) came together to form small galaxies that kept merging and growing. The last image shows the universe at middle age about seven billion years ago when huge galaxies (yellow) spun inside dark matter halos (green).

but also growing bigger. The most popular version of the dark matter theory says that galaxies began small and grew over time through collisions and slow accumulation of material from their surroundings.

And these collisions aren’t just things of the past, Navarro notes. Witness the Antennae galaxies, two galaxies caught in a cosmic tussle 63 million light-years from Earth. Their mutual gravity has pulled out two long streamers of luminous matter that resemble the antennae of a cockroach. Closer to home, the Andromeda galaxy, now hurtling toward us at 300,000 miles an hour, will merge with the Milky Way in several billion years, theorists predict.

It wasn’t the orderly shapes of mature galaxies but the messy shapes of baby galaxies that captured the imagination of astronomer Chuck Steidel at the California Institute of Technology. His work has led to the discovery of more than 2,000 early galaxies—sometimes at a rate of a hundred a night—providing important data for theorists like Abel and Navarro. And it all began with a trek to a remote mountaintop in Hawaii.

As Steidel and three of his closest colleagues drove slowly up the narrow, bumpy road to the 13,796-foot summit of Mauna Kea, they knew this was their chance to crack open the secrets of the early *(Continued on page 22)*



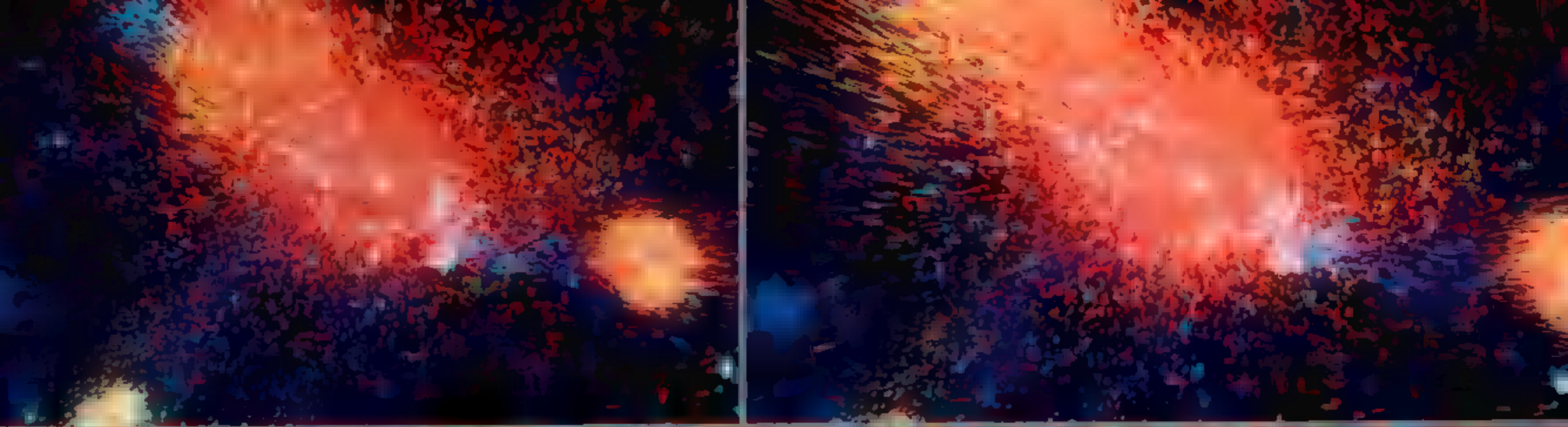
When they exploded, the

stars seeded the universe, and the next generation of stars,

with the first supply of

"A BIG TRAIN WRECK." That's how Michael L. Norman describes the meeting of two galaxies in his pioneering computer simulation of the history of the universe. His one-minute animated film, from which these frames were taken, represents what Norman, a physics professor at the University of California, San Diego, calls "pictures of theory." Feeding numerical calculations for dark matter, interstellar gas, gravity, and star formation into a supercomputer, Norman produced a three-dimensional illustration of stellar activities, much of which agrees with recent real-life images from the Hubble Space Telescope. Covering a few billion years in time, the sequence here begins with the explosive merger of two large galaxies—both the products of earlier collisions—then zooms into the cauldron of activity at the center of the new galaxy in progress. The movie visualizes how the older stars, identified by their cooler red temperatures, are dislodged from their orbits and strewn like spilled paint. The intense white and yellow areas represent swarms of new hotter stars igniting in a turbulent flood of gas. Fueling the creation of realistic simulations are supercomputers using dozens of linked processors and computational techniques from nuclear weapons laboratories. "Do pictures of theory look like pictures of nature?" asks Norman. "Yes they do."

MICHAEL L. NORMAN AND BRIAN O'SHEA, COX, AND DEBRA COX, ROBERT
BUTTS, AND GUY LEVY, WITH THE WGBH BOSTON, "RUNAWAY
UNIVERSE"



heavy elements, including the oxygen we breathe.

Fossil Light

NATURE'S VERSION of a powerful telescope, the galaxy-rich cluster known as Abell 1689 (right) magnifies the faint light from early galaxies. That ancient light shows up as curved streaks in this newly released image from the Hubble Space Telescope. Light rays from a distant galaxy are bent and focused (diagram below) as if by a lens when they hit the gravitational field of the Abell cluster with its high-beam galaxies and dark matter stored. By measuring the redshift of the streaks—the amount that wavelengths of light have stretched as the universe expands—astronomers calculate the time and distance that starlight has traveled. Says Narciso Benítez of Johns Hopkins University, “This may be our deepest view of the optical universe.”



z=1.9

The greater its redshift of z , the further away in time and space a visible object is from Earth. The measurement for this remote galaxy—seen in duplicate as its light was split into two parts by the intervening galaxy cluster—indicates that its signal dates back to 1.3 billion years after the big bang. That makes it one of the most distant galaxies ever spotted.

z=4.9

Light from this star system, also seen in a dual image, arrives from a time of active galaxy building when the universe was 3.6 billion years old.





universe. If the skies remained clear, they were about to observe the heavens with the largest visible-light telescope in the world, the Keck.

It was September 30, 1995, and Steidel, at only 32, hoped to accomplish what no one had ever done—detect in wholesale numbers galaxies so distant that the light they emitted more than 12 billion years ago was only now reaching Earth. That meant the galaxies would appear as they did when they were infants. If Steidel and his collaborators could find enough of them, these youngsters might reveal not only how galaxies first formed but also how they changed over time, and how they were distributed across the universe.

Until then astronomers hunting distant galaxies hadn't made much progress. They had found a few oddball objects that glowed extremely brightly, but they had failed to find the run-of-the-mill, remote galaxies thought to be prevalent in the cosmos. Most astronomers figured they would need bigger telescopes to find these faint objects. But Steidel had another idea: Maybe galaxies that hailed from the early universe had already been detected but no one had been able to pick them out from the thousands of other objects on sky maps.

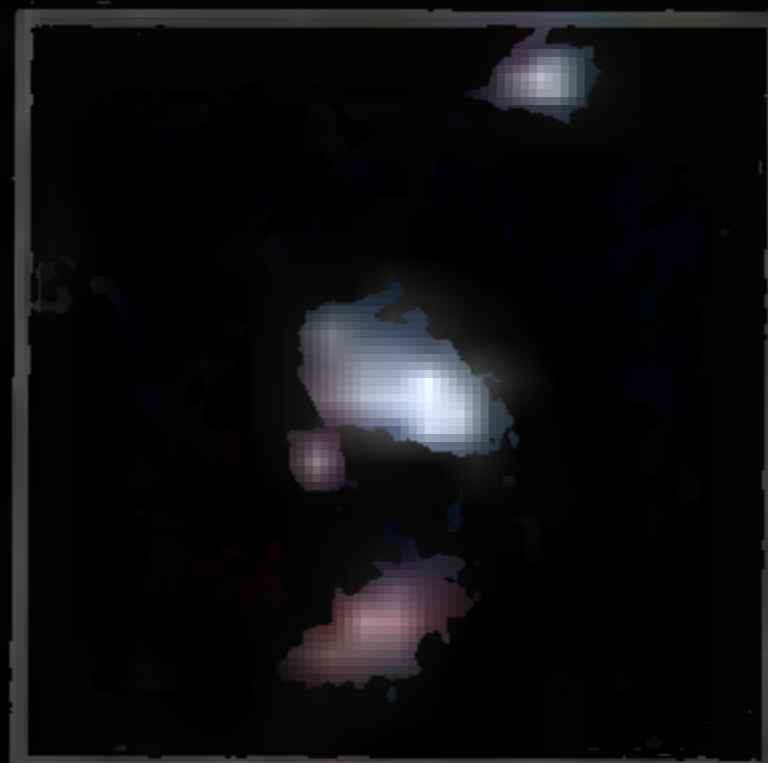
Like a few other astronomers before him, Steidel realized that distant galaxies have their own signposts. They contain an abundance of hydrogen gas, as does the vast expanse of intergalactic space between them and Earth. When the ultraviolet light emitted by stars in galaxies is above a certain energy level, hydrogen gas absorbs it. The light never reaches Earth. So before Steidel and his collaborators ever dreamed of coming to Keck, they recorded galaxies that showed up brightly in red and green filters but were absent when viewed through an ultraviolet filter. They called these galaxies Lyman break galaxies, after Theodore Lyman, a physicist who pioneered studies of ultraviolet light in the early 20th century.

According to the color criterion, the faint galaxies Steidel's team had found prior to coming to Mauna Kea ought to be remote. But were they? To measure distance, the astronomers had to determine how much light from a galaxy had been stretched, or reddened, by the expansion of the universe. The greater this redshift, the greater the distance from Earth. A galaxy at a redshift of three, for instance, corresponds

Cosmic Plunder

ONLY THE YOUNG ONES catch Chuck

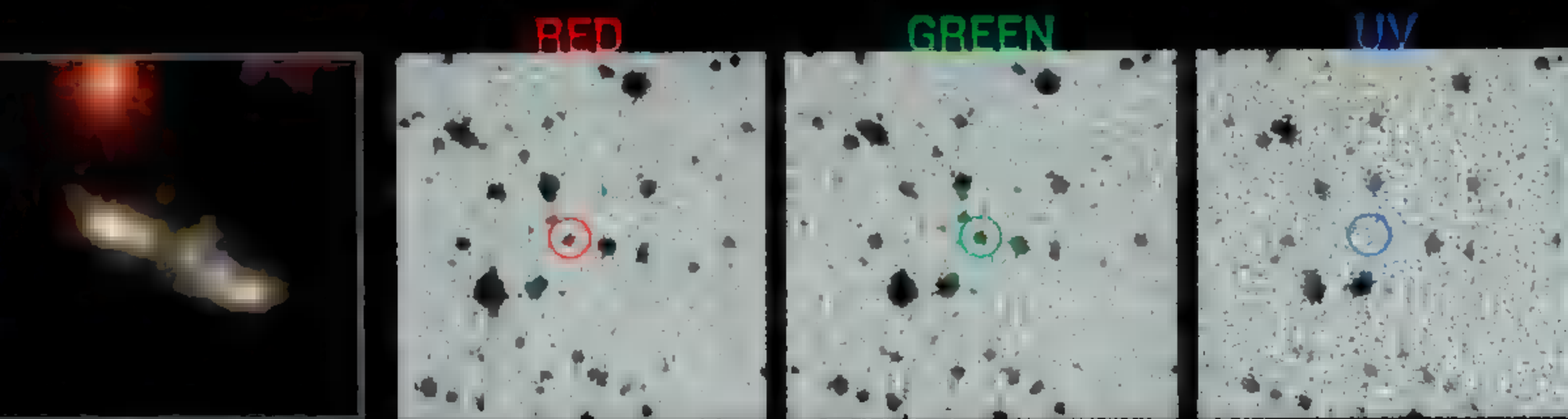
Steidel's eye. The astronomer from the California Institute of Technology is wildly successful at finding newly formed galaxies from the early universe. How? By watching them disappear. Steidel and his colleagues made their discoveries by studying a map of galaxies sighted through red, green, and ultraviolet filters (panel at lower right) on ground-based telescopes. They saw that with the UV filter, certain galaxies had vanished. Steidel knew that these must be early, very distant galaxies; hydrogen gas that was plentiful in the early universe was absorbing the UV light. Using the powerful Keck telescope in Hawaii, he has now confirmed more than 2,000 galaxies dating back to the first two billion years of the universe. A deep-field probe by the Hubble telescope has sighted some of these infant galaxies (below).



to a distance of about 12 billion light-years.

For faint galaxies, redshift can only be determined with a telescope as powerful as Keck. Now Steidel and his colleagues Mark Dickinson, Mauro Giavalisco, and graduate student Kurt Adelberger found themselves with two nights on the telescope. If they could demonstrate that their color method worked, they would have a foolproof way to find not just one or two distant galaxies but dozens—even hundreds.

Years before, Steidel and his collaborators had already picked out their first target. Residing in the constellation Eridanus, it was the brightest



Lyman break galaxy the team had yet found. “We figured if we were going to be successful, it was going to be with this object,” Steidel recalls. But he also knew that from Mauna Kea, the starlit body rose above the horizon for only an hour each night.

The fleeting hour that Keck stared at the galaxy, however, turned out to be enough. Just as Steidel had predicted, the spectrum revealed that the galaxy resided 12 billion light-years from Earth. Steidel was thrilled that his technique could find an ordinary galaxy so far away.

On the next night at Mauna Kea the astronomers

attempted an even more ambitious feat. Taking full advantage of the power of the Keck spectrograph, they attempted to measure the distance simultaneously to several galaxies in the same patch of sky. To do so, they used a mask, a piece of aluminum about the size of a cookie sheet, which had several narrow slits carefully cut out. Each slit precisely aligned with the position of a target galaxy. With the mask in place, only the light from each target galaxy could enter Keck’s spectrograph. By the end of that night the young astronomers had found 15 galaxies with redshifts greater than three.

On that night, slightly giddy from the high altitude, Steidel played for the first time at Keck the dreamy, lullaby-like music of the alternative rock band Mazzy Star. It would soon become a coda for each night Steidel observed at Keck and a special bond between him and Dickinson, whom he had met when they were both college disc jockeys at Princeton in 1980.

By 1997 Steidel's team had bagged another 250 Lyman break galaxies and an intriguing pattern emerged. To the surprise of the astronomers, those distant galaxies were strongly clustered in a way that revealed how dark matter is distributed. The

galaxies evolved from the simple universe of dark matter and elemental gases described by Tom Abel. Without such winds we can't easily explain the appearance of the visible universe today.

Beginning where Steidel's team left off, astronomer Sandra Faber of the University of California, Santa Cruz, is poised to break new ground in the study of galaxy formation. She and her collaborators hope to piece together how baby galaxies, like the ones found by Steidel, developed into the galaxies around us today.

Last March, wearing a navy blue jumpsuit that made her look more like an auto mechanic than

“We’re collecting the photo album of the life history of the universe for the first time: the baby pictures, the teenage pictures, the grown-up pictures.”

first galaxies formed in the densest regions of the universe, which correspond on average with the densest regions of the cosmos today, where we find large galaxy groups and clusters. As time went on and gravity exerted its inexorable pull, regions of lower density also gave birth to galaxies, blazing with newborn stars.

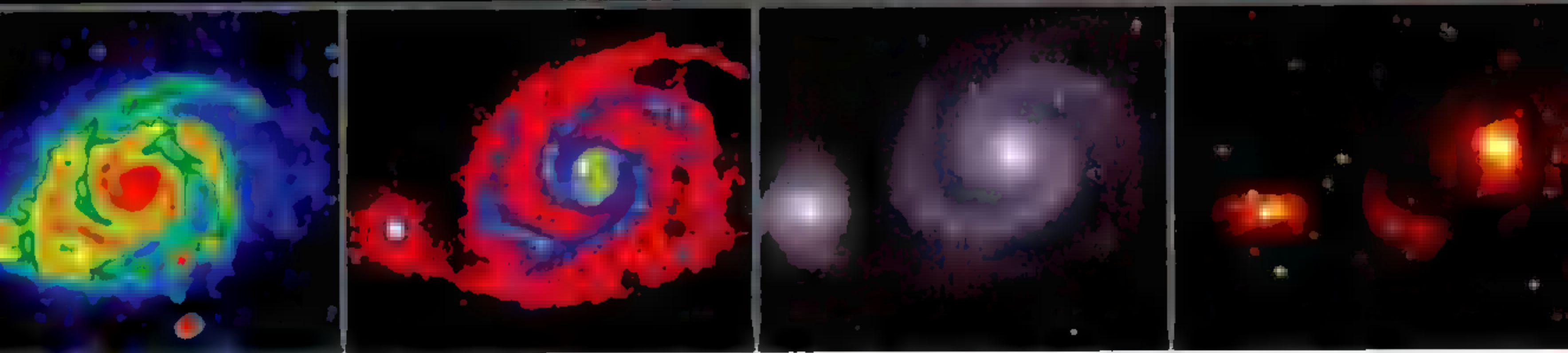
JUST AS IMPORTANT was another discovery made by Steidel and Kurt Adelberger in 2001: Powerful winds were rushing out of the Lyman break galaxies, proving that there was more to the story of galaxy formation than dark matter. The winds, driven by supernova explosions, were so strong they enabled ordinary matter to temporarily escape the grasp of dark matter, which was unaffected by the winds. Not only did the winds clear out a vast bubble around their home galaxy, they carried hydrogen and other elements into surrounding space. The heavy elements, which could only have been forged inside stars, set the stage for future generations of galaxies.

“For a few weeks I dreamed about winds and thought about winds while I was eating my cereal in the morning and while I was in the shower and while I was Rollerblading to work,” says Adelberger, now at Harvard. These winds added a layer of complexity to the story of how

a surveyor of the heavens, Faber strode through the chilly rooms of the Keck II observatory, which began operating in 1996 next to the first telescope. She had come to Mauna Kea to install the state-of-the-art Deep Imaging Multi-Object Spectrograph (DEIMOS) that she and her team had designed. The 20,000-pound device, which has to be slid in and out of position on metal tracks, can simultaneously analyze the light from as many as 130 distant galaxies.

“We’re collecting the photo album of the life history of the universe for the first time,” she said. “The baby pictures, the teenage pictures, the grown-up pictures.” Astronomers are even taking snapshots of what the universe looked like before galaxies were born. If we used the birth of galaxies as our reference point, she said, then the hot and cold spots in the cosmic microwave background would be the prenatal pictures.

Faber is homing in on the process of galaxy formation from mid-childhood to early adulthood. At redshift three, galaxies were blobby and irregular. At redshift one, corresponding to a time when the universe was little more than half its current age, the shapes of galaxies cataloged by Edwin Hubble were beginning to fall into place. In between is a mystery interval from 12 to 8 billion years ago in which galaxies are notoriously hard to detect. During this largely



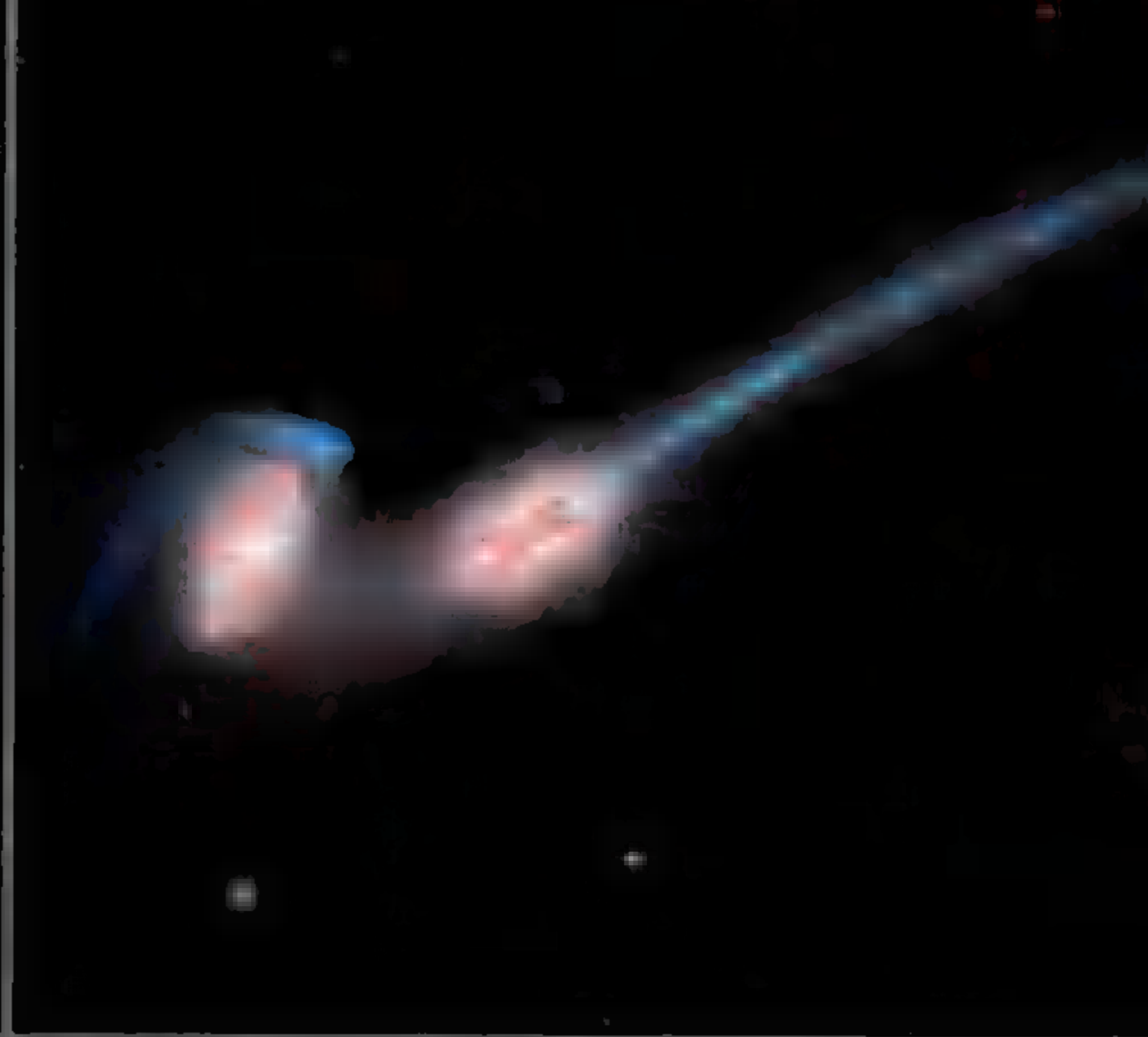
CLOSE ENOUGH to see in detail in visible light, the Whirlpool galaxy, 28 million light-years away, flashes tendrils of new blue stars in an image captured by an amateur's telescope. Hubble emissions (far left) reveal strong magnetic fields along the galaxy's spiral arms. A mid-infrared portrait (second from left) detects dust patterns and new star sites, while a near-IR image (third from left) shows the galaxy's backbone of old stars. X-rays show areas of hot gas (yellow), some of it near black holes.

uncharted interval galaxies matured, taking on their final mass and familiar shapes. A goal of DEIMOS is to open this interval to view.

"The spectrum of the night sky is the great enemy," she said, "an incredible picket fence of glowing emission lines"—the bright light emitted by atoms and molecules at sharply defined wavelengths. This picket fence in Earth's atmosphere overwhelms the faint infrared light from galaxies her team wants to study. There's

one saving grace, however. The emission lines are narrow, while those from distant galaxies are much broader. With that in mind Faber's team designed DEIMOS to greatly expand, or disperse, the infrared spectrum. That enables the team to look between the pickets and focus on the light emitted by the galaxies.

That's when the fun begins. The brightness and shapes of the galaxies at different redshifts—and myriad other properties that can be observed

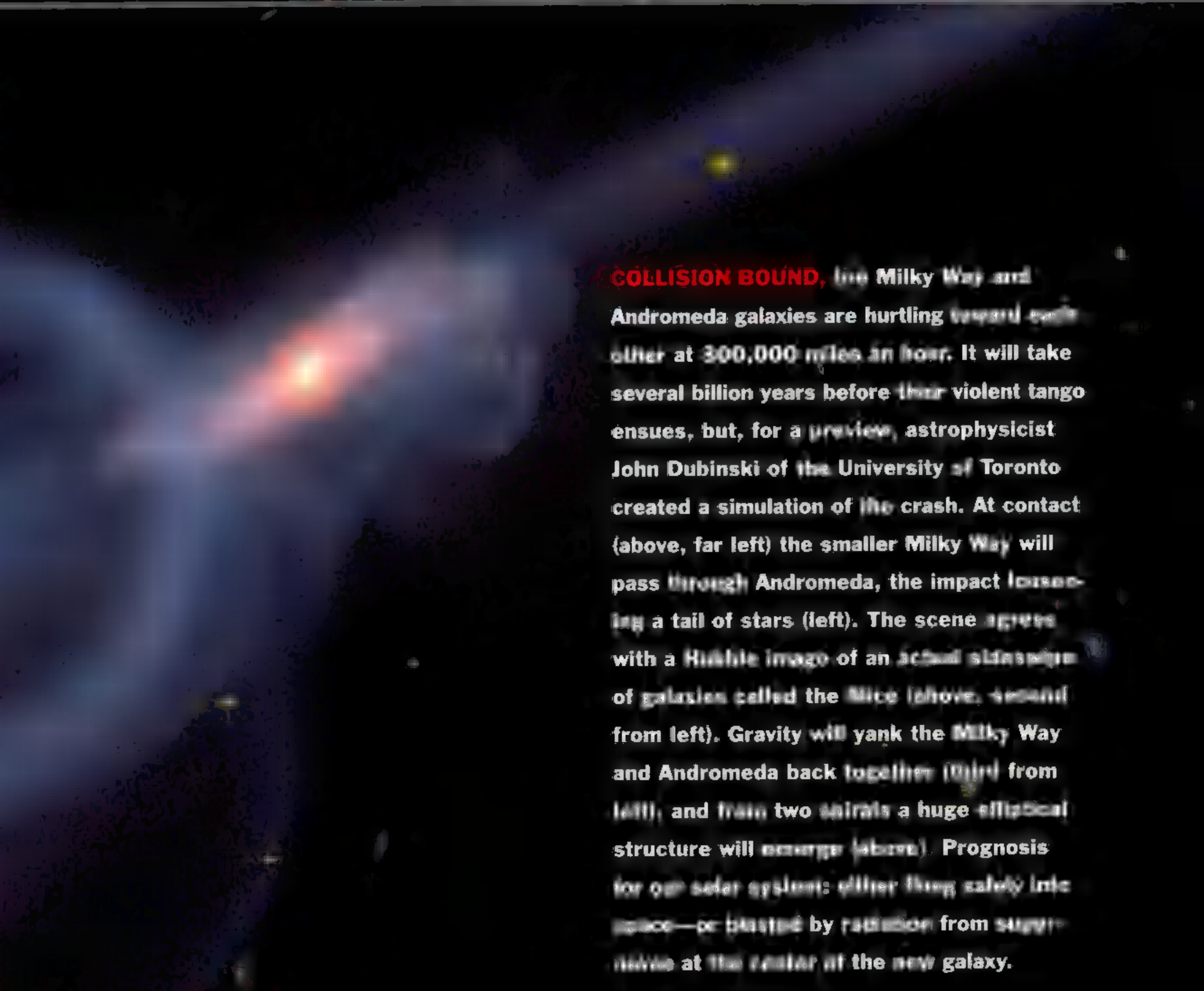
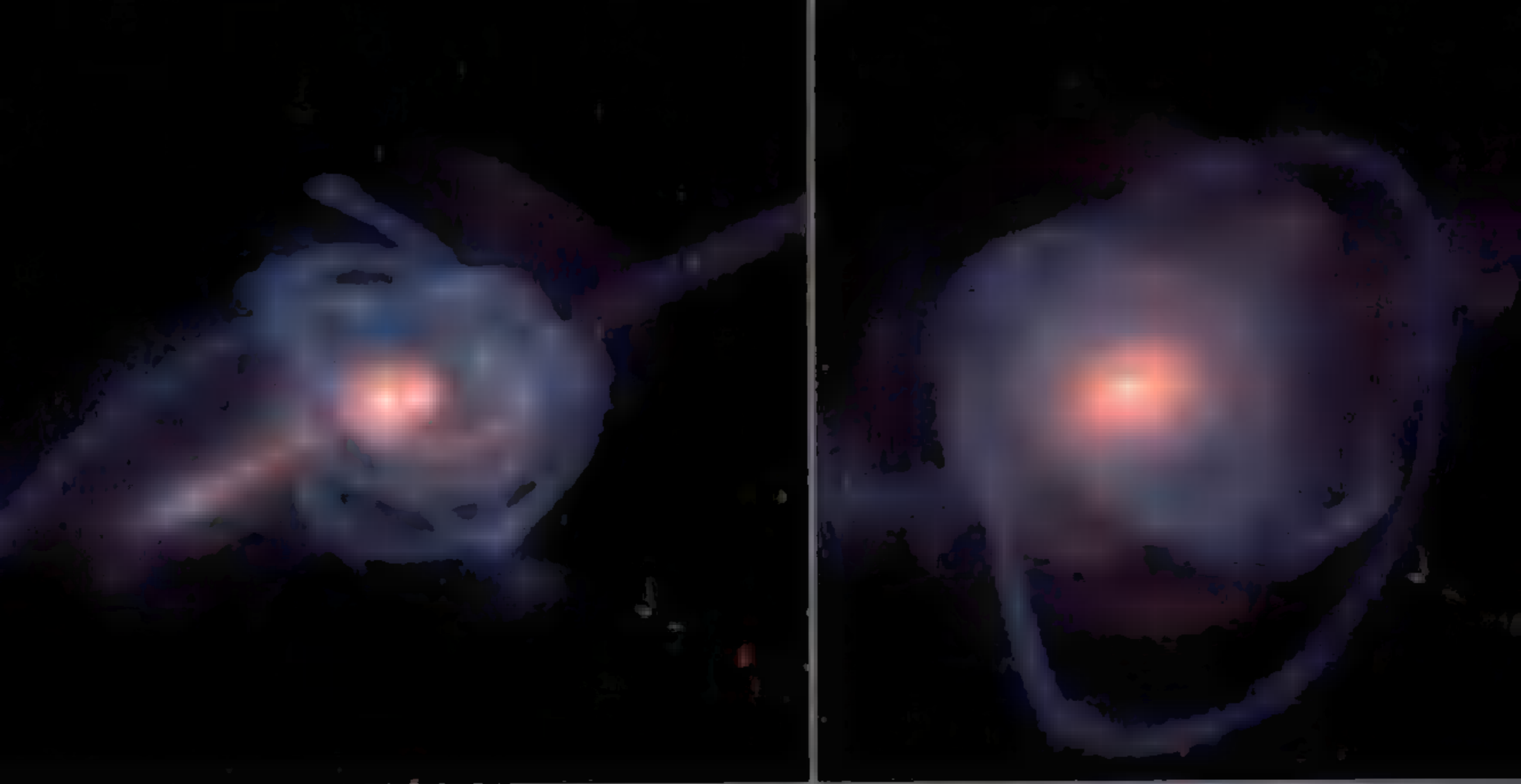


Today we know that the

Milky Way contains more than 100 billion

stars and that there





COLLISION BOUND, the Milky Way and Andromeda galaxies are hurtling toward each other at 300,000 miles an hour. It will take several billion years before their violent tango ensues, but, for a preview, astrophysicist John Dubinski of the University of Toronto created a simulation of the crash. At contact (above, far left) the smaller Milky Way will pass through Andromeda, the impact loosening a tail of stars (left). The scene agrees with a Hubble image of an actual slingshot of galaxies called the Mice (above, second from left). Gravity will yank the Milky Way and Andromeda back together (third from left), and from two spirals a huge elliptical structure will emerge (above). Prognosis for our solar system: either being safely into space—or blasted by radiation from supernovae at the center of the new galaxy.

are some 100 billion galaxies in the universe.

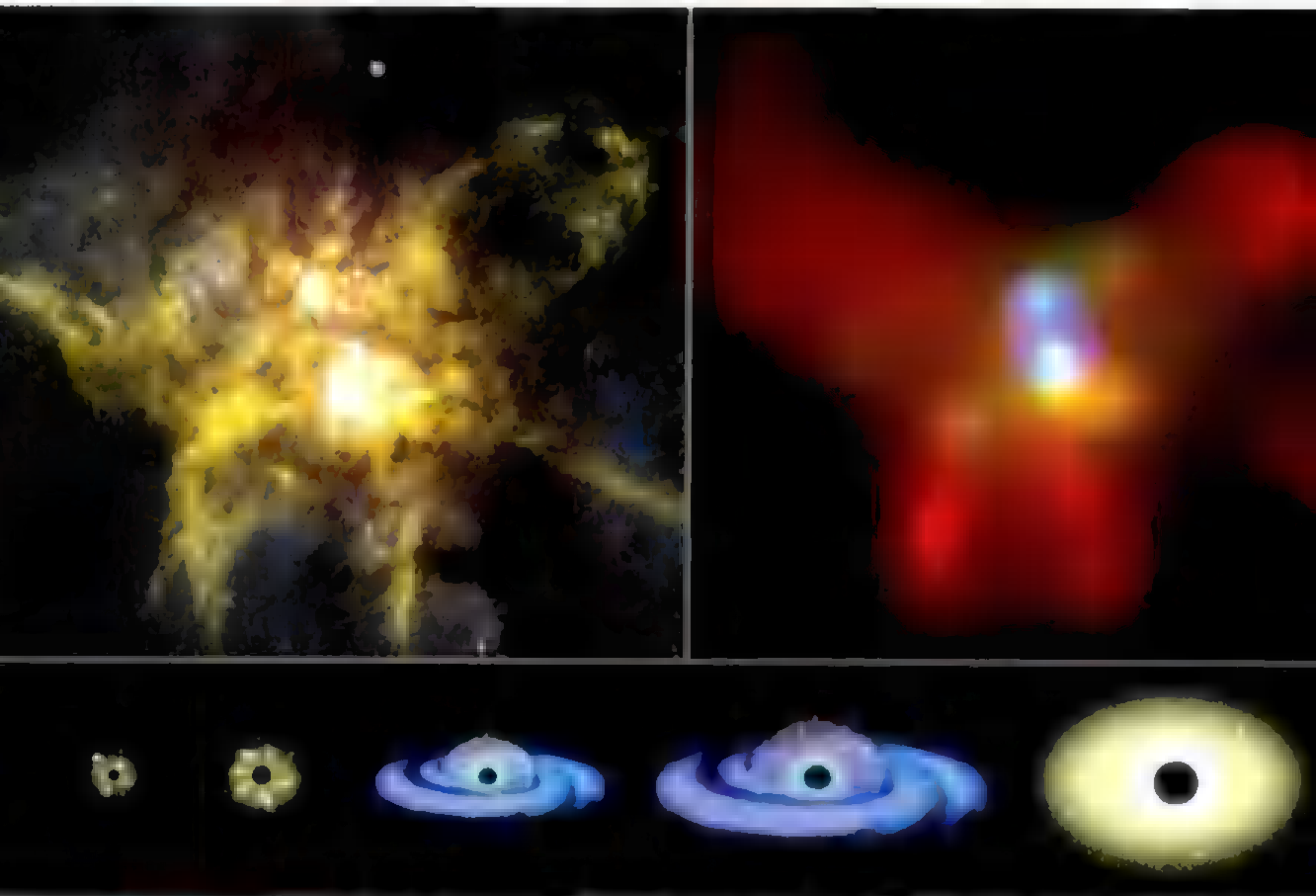
A veil still conceals what happened during the

thanks to DEIMOS—can indicate how the small, scruffy looking galaxies in the early universe formed the familiar galaxies that Hubble described in the 1920s.

Perhaps the most important of these properties is mass, Faber said. By measuring the mass of galaxies observed at different times in the universe, Faber hopes to trace the steps by which galaxies merge and grow larger. She would also like to learn why spiral galaxies, which are easily disturbed by collisions, are so abundant.

The answer could be that in recent times spirals have grown by slowly drawing in material rather than through collisions. If her reasoning is correct, spiral galaxies should be forming stars at a gentle rate rather than in bursts that accompany collisions. Over the next few years, DEIMOS should provide the answer.

A few hours after Faber finished her work for the day, the domes of the twin Keck telescopes slid open and the instruments drank in the faint light from some of the most distant objects in



DOUBLE TROUBLE: A pair of supermassive black holes dwells deep within a single galaxy, NGC 6240, 400 million light-years from Earth. Astronomers believe the unusually bright, messy galaxy (optical image, top left) was formed from the collision of two smaller galaxies, each containing a black hole. Within a few hundred million years the two black holes, which circle each other (x-ray image, top right), are expected to merge—one way that black holes are thought to grow. A sequence of formations from a cluster to a large galaxy (art, above) shows how black holes vary in proportion to the amount of star material, reaching sizes equal to millions of times the sun's mass. Such discoveries bring astronomers closer to deciphering the blueprint for galaxies, nature's grandest structures.

first, crucial period of galaxy formation, which astronomers have dubbed the Dark Ages.

the heavens. Down in Waimea, 48 miles away, two groups of astronomers were gathered inside an industrial-style low-rise building to relay instructions to operators on the mountain. Since 1996, a year after Steidel began his work, the telescopes have been directed from control rooms in this building.

In one room Arjun Dey of the National Optical Astronomy Observatory in Tucson, Daniel Stern of NASA's Jet Propulsion Laboratory, veteran observer Hy Spinrad of the University of California, Berkeley, and graduate student Steve Dawson were aiming the Keck I telescope at a catalog of faint galaxies, hoping to peer deeper than ever before into the universe—a billion years farther back in time than the galaxies found by Steidel. These are galaxies that glow brightest when they are observed through filters that allow only certain wavelengths of light to pass. The wavelengths correspond to a specific ultraviolet radiation emitted by hydrogen atoms that has been highly redshifted by the expansion of the universe. The filtered light was an indication, but not a confirmation, that the galaxies were located near the edge of the visible universe.

In the control room next door, meanwhile, Caltech astronomer George Djorgovski was also studying the distant universe. Using Keck II, he was trying to take the spectra of one of the most distant known quasars, the brilliant beacons that emanate from the cores of some galaxies. This quasar was so far away that to reach Earth, its light pierced regions so far back in time that they hadn't yet been blasted by radiation from the first generation of stars in the universe.

Back at the Keck I control room, Dey and his colleagues were staring at a bunch of squiggly black lines on the computer screen. After several hours of analysis, they came to a consensus. At a redshift of 5.74, the light that had fallen on the Keck telescope had left a galaxy known as LALA J142546.76+352036.3 more than 13 billion years ago. It appeared they had found the third most distant galaxy known. But after a final check, Dey and his collaborators smiled even more broadly and gave each other high

fives. For on this night, March 13, 2002, the astronomers had found the second most distant galaxy known in the universe (after another galaxy discovered at Keck with a redshift of 6.56).

SO WHAT DOES IT ALL MEAN? Have astronomers finally solved the riddle of how galaxies were born and evolved? Not quite, says William C. Keel of the University of Alabama, but astronomers are likely to put pieces of the puzzle together over the next decade. With mammoth new maps of the nearby cosmos, scientists today can study 13 billion years of galaxy evolution. But a veil still conceals what happened during the first, crucial period of galaxy formation, which astronomers have dubbed the Dark Ages. It began a few hundred thousand years after the big bang and ended perhaps a billion years later. During the first chunk of that time, the universe was truly dark. But later on, the first glimmers of starlight emerged and a telescope that has enough light-gathering power and is sensitive to just the right wavelengths, should be able to detect them.

A key task, already begun, will be to build a telescope to penetrate the veil. Keel and many astronomers are pinning their hopes on NASA's James Webb Space Telescope, the proposed successor to the Hubble Space Telescope, scheduled for launch about 2010. Equipped with a mirror capable of collecting six times as much light as Hubble, the telescope, with its advanced infrared and visible light instruments, will be able to detect objects much dimmer and farther away than those observed by any other telescope. That should give scientists the power for the first time to peer into the Dark Ages and to record the faint, warm light from some of the very first stars and galaxies, objects that can now only be seen in computer simulations like those on Tom Abel's laptop.

Until then the final frontier of galaxy formation awaits us, out in the darkness. □

WEBSITE EXCLUSIVE

Watch simulations of the birth and development of galaxies as shown in this story at nationalgeographic.com/ngm/0302.



S Shattered SUDAN

DRILLING FOR OIL, HOPING FOR PEACE

The oldest civil war in the world is being fought, on one side, by men who wander like demented hospital orderlies across the primordial wastes of Africa.

I follow them one hot morning as they flee a government ambush in the oil fields of southern Sudan. One of their comrades has just been shot dead, his body abandoned on a parched savanna that hides nearly 20 billion dollars' worth of low-sulfur crude. We retreat for hours under a scalding sun, crossing in the process a vast, cauterized plain of cracked mud. I pause a moment to watch them: an ant-like column of rebels dressed in bizarre homemade uniforms of green cotton smocks and white plastic slippers,

**BY PAUL SALOPEK
PHOTOGRAPHS BY RANDY OLSON**





FALLEN

In the ancient Tenthra quarry, ancient Nubian statue from the seventh century B.C. When their Nubian ancestors ruled all of Egypt. Today Sudan's government doesn't even control the whole country. Since independence from Britain in 1956, the nationalistic leaders have fought to extend their power throughout the rebellious south, waging a civil war for all but 18 of the past 48 years. Despite recent peace talks, Sudan remains locked in conflict over oil and religious identity and the south's resources, water, land, and oil.



limping into the heat waves of distance. Five casualties bounce in stretchers. They suffer their bullet wounds in silence. A boy marching in front balances a car battery on his head. He is the radio operator's assistant. Every few hundred yards he puts the battery down and empties blood out of a shoe.

When we finally reach a tree line, the fighters strip off their clothes and jump into a bog. The water stinks. It is infested with larvae of guinea worms, which, once ingested, burrow painfully through the body to the legs, and are extracted by making a small incision; you reel the worm out slowly, day after day, by winding it on a small stick. All around us, half-naked people move feebly through the thorn forest: ethnic Dinka herders displaced from the contested oil fields by fighting between rebels and the central government based in the faraway capital, Khartoum. Their children, stunted and ginger-haired from malnutrition, clamber in the trees. They are collecting leaves to eat. This awful

place, I learn, is called Biem—a safe haven, such as it is, of the 40,000-strong Sudan People's Liberation Army.

"You cannot reclaim what is lost," the sweating rebel commander says, squatting in the shade of an acacia, "so you just keep fighting for what little you have left."

He is trying to console himself. But I see little solace for the epic tragedy of Sudan. It is April 2002, and Africa's largest country is lurching into its 19th uninterrupted year of warfare—the latest round of strife that has brutalized Sudan, off and on, for most of the past half century. More than two million Sudanese are dead. We just left the latest fatality sprawling back in the yellow grasses, a bullet through his brain. And thousands of scarecrow civilians stagger through the scrub, starving atop a lucrative sea of petroleum.

Numbly, I crawl inside an empty grass hut to be alone. Lying flat on my back—depressed, exhausted, stewing in my own helplessness—I



“You cannot reclaim what is lost,” the sweating rebel commander says, squatting in the shade of an acacia, “so you just keep fighting for what little you have left.”

try to remind myself why I have returned to Sudan: Because peace is in the air. Because oil, newly tapped by the government, is shaking up the wretched status quo in Africa’s most fractured nation. Because the long nightmare of Biem—and a thousand other places like it in Sudan—may soon be over.

Bulging like a gigantic hornet’s nest against the shores of the Red Sea, Sudan has rarely known stability. Civil war erupted even before the nation gained independence from Britain in 1956. (A frail peace lasted between 1972 and 1983.) The roots of the violence have never changed: British-ruled Sudan wasn’t a country; it was two. The south is tropical, underdeveloped,

and populated by Dinkas, Nuers, Azandes, and some hundred other ethnic groups of African descent. The north, by contrast, is drier, and wealthier—a Saharan world with strong links to the Muslim Middle East. Shackled together by lunatic colonial borders, these two groups—northern Arabs and southern blacks—have been at odds since the 19th century, when northern slave raiders preyed on the tribes of the south.

At present, the rebel Sudan People’s Liberation Army, or SPLA, controls much of the southern third of Sudan. Its insurgents sometimes carry spears as well as Kalashnikovs and are fighting for greater autonomy. The northern government in Khartoum, *(Continued on page 40)*



POWER

Seeking to win over visiting Western journalists, government officials gather at the home of the minister of information (above, at center) in the capital of Khartoum. Sudan has long been ruled by a small circle of wealthy northerners, who, because of their Muslim faith and Arabized culture, consider themselves Arab instead of African. Islam and Arab culture came to Sudan through trading centers like the ruined Red Sea port of Suakin (left). By the 14th century the religion had been widely adopted by northern merchants and kings.

OIL

Hoping to make a little money from Sudan's ocean black gold, a woman sells to roughnecks at an oil rig near Bentiu. When oil found in the south two decades ago, the government planned to pipe it north for refining. In 1983 this and government violations of a 1972 peace treaty led to rebel attacks, reigniting the civil war. Guarded by government troops, a multinational consortium pumps on.





SUDAN AT A GLANCE

AREA

967,500 square miles

POPULATION

33 million, with more than 60 ethnic groups

CULTURES

10% African

39% Arab

9% other

RELIGION

70% Muslim

25% traditional African

5% Christian

CAPITAL

Khartoum, population

7 million

GDP PER CAPITA

\$1,878

INTERNALLY DISPLACED

4 million, mostly

southerners



Most of Sudan's wealth flows to Khartoum (above), into the hands of a privileged few who have imposed strict Islam on the country and are exploiting southern resources. The Sudd swamp (below) had long isolated the south from Islam. A government plan to divert its water to grow cash crops in the north contributed to tensions that restarted the civil war. Caught in the middle, a Nuer man (left) works in an oil field. The pay is good, but oil funds a conflict ravaging his homeland.



REFUGEES

490,000, mostly southerners

DEATHS DUE TO WAR

More than 2 million since 1983, mostly southern civilians

COST OF WAR

\$1 million a day spent by government on military

OIL REVENUES

More than \$2 million a day

OIL RESERVES

Estimated 70 billion barrels

FOREIGN DEBT

\$15 billion

MAIN EXPORTS

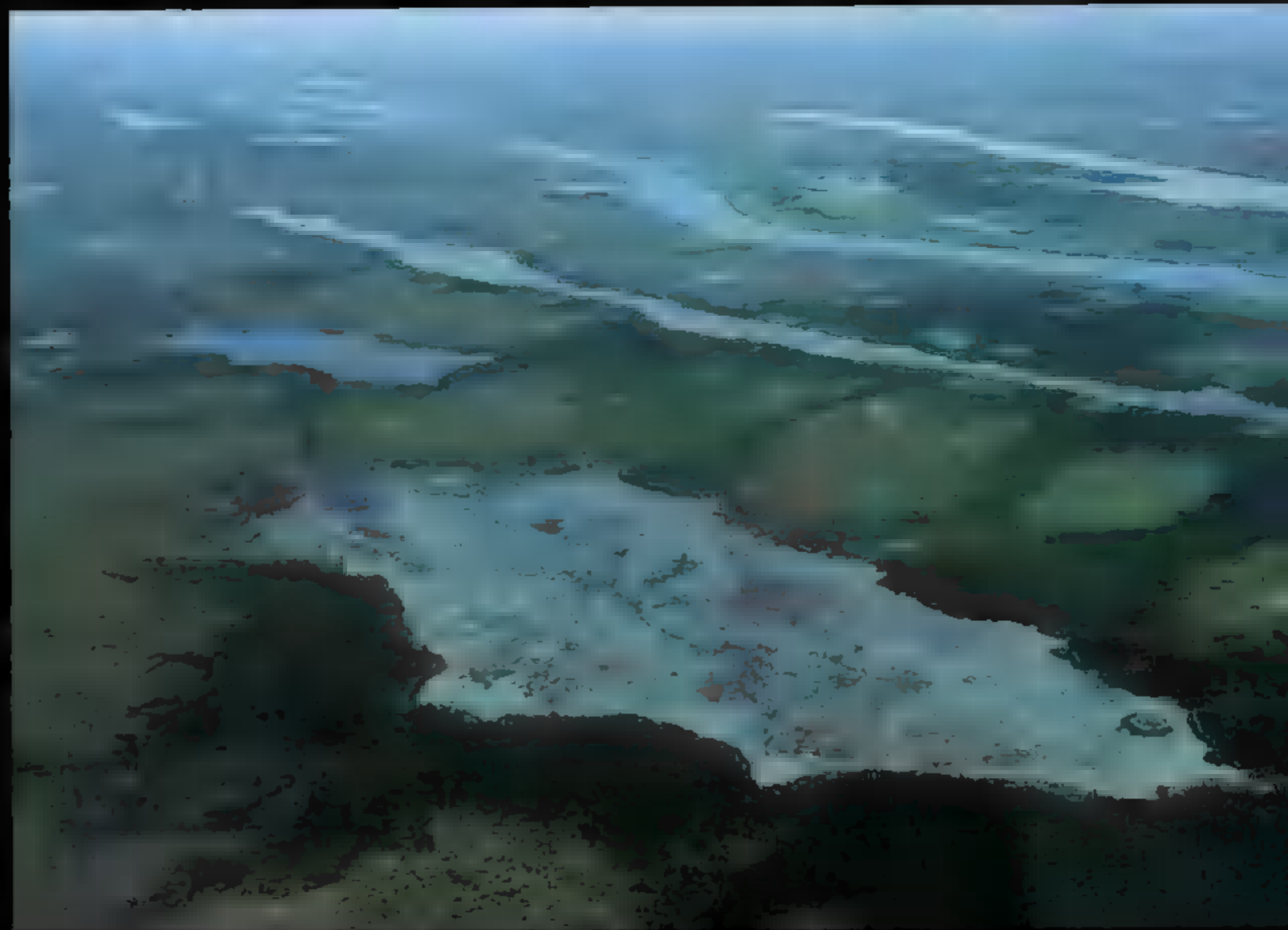
Oil, cotton, sesame, peanuts, livestock, gum arabic, sugar

EMPLOYMENT

60% government workers, herders, farmers

UNEMPLOYMENT

31%



A NATION DIVIDED

Arab North, African South, and Contested Middle

SAUDI ARABIA



Snaking across the savanna, the northern boundary (in red) of southern Sudan marks the frontier of Arabic Islamic culture and the rough front line in a 20-year-old civil war. The army and government militias are fighting a rebel alliance of southerners, Arab northerners who oppose the ruling elite, and non-Arab northerners seeking self-determination. Most battles erupt around the government oil fields.

now dominated by Islamic fundamentalists, drops bombs on them from old Russian-made cargo planes and employs famines and modern-day slavery as crude weapons of mass destruction. So far the death toll—mostly among southern civilians—exceeds that of many of the world's recent conflicts combined, including Rwanda, the Persian Gulf war, the Balkans, and Chechnya. Four million Sudanese have been displaced by violence and starvation. Yet the calamity of Sudan unfolds largely without witnesses—an apocalypse in a vacuum. Until now.

Two factors are bringing new hope to Sudan. Neither has anything to do with the suffering of millions of Sudanese. Both involve the self-interest of outsiders.

First, the U.S. war on terrorism appears to be pressuring reforms in the northern Islamist regime. When a military coup backed by the radical National Islamic Front toppled Sudan's last

democratically elected government in 1989, the country plunged into a new dark age. Independent newspapers were banned. Labor unions suppressed. The north's moderate Islamic parties were hounded into exile. The civil war escalated to the drumbeat of jihad—holy struggle against indigenous religions and Christianity in the south. Outlaws ranging from Osama bin Laden to Carlos the Jackal settled into mansions in Khartoum's sandy outskirts. And the fundamentalists' secret police, the feared *mukhabarat*, added a new word to the lexicon of political repression—the “ghost house,” or unmarked detention center.

Recently, however, Khartoum's extremists have begun mellowing. Chafing under U.S. economic sanctions, they have begun cooperating with the global war on terror. Desperate to shed their pariah status, they have bowed to Western pressure to enter peace negotiations in the civil war.

COMMODITY

Responding to an ad broadcast throughout Sudan—even in war zones—a southern man traveled hundreds of miles to cut sugarcane on the Kenana plantation in the north.

The huge commercial farm, which depends on irrigation water drawn from the White Nile, employs 16,000 people and earns Sudan 70 million dollars a year in foreign currency. Cash crops and livestock accounted for almost all export earnings before oil started flowing in 1999.



When the Cessna touches down, the pilot dumps my bags and leaves. His shiny airplane stands out dangerously in the bleakest liberated zone in the world.

In October 2002 the government and the SPLA signed a fragile cease-fire.

The second—and perhaps more profound—force of change in Sudan is less noble. It is about something the whole world wants. It is about oil.

In May 1999 engineers in Khartoum opened the tap on a new thousand-mile-long pipeline that connects the Muglad Basin, a huge, petroleum-rich lowland in the south, to a gleaming new tanker terminal on the shores of the Red Sea. The Muglad Basin, a prehistoric lake bed, is said to hold some three billion barrels of crude—nearly half the amount of recoverable oil that lies under the Arctic National Wildlife Refuge in Alaska. This bonanza, pessimists say, is just one more prize for the warring parties to fight over. But oil also has fueled renewed international interest in Sudan. And diplomats are more optimistic.

“It’s a no-brainer,” says a U.S. expert familiar with Sudan’s many woes. “The rebels control much of the oil country. The government has access to the sea. They need each other to get rich.”

A Canadian geologist who is mapping the Muglad Basin agrees: “Every Sudanese won’t be driving a Mercedes tomorrow—we’re not talking about another Saudi Arabia here,” he tells me, “but the reserves are big enough to transform Sudan forever.”

There are good reasons for skepticism. Sudan’s grievances are very old and complex. They confound even the Sudanese. For many, the north-south war is rooted in the old toxic relationship between Arab master and African servant. For the religious, it is a contest between northern Islam and southern indigenous religions and Christianity. For the impoverished herdsmen on the front lines, it is a local skirmish over a water hole or favorite pastureland: Violent disputes among Sudan’s hundreds of ethnic groups have been inflamed—and manipulated—by the main warring parties. Yet oil cuts, literally, across all of Sudan’s overlapping wars. Better than any road, or river, or political theory, the shining new pipeline leads the way through a labyrinth of misery in the

Horn of Africa that defies easy interpretation.

I have traveled before to Sudan. Like many journalists, I was sent there to chronicle a freak show of human suffering: endless civil war, recurrent droughts, mass starvation, slaving raids, and epidemics of killing diseases. Today, however, I am on a different mission. I will follow the flow of Sudan’s oil wealth from the implacable war zones of the south to an ultramodern export terminal on the Red Sea; to the country’s future.

This will not be an easy journey. I will be forced to complete it in disjointed segments, side-stepping battlefronts, accommodating roadless deserts, avoiding suspicious bureaucrats—an erratic process that mirrors life in Sudan.

I pressed my ear against the pipeline once: The Nile Blend crude oozing inside emitted a faint liquid sigh. I listened hard, sweating under a tropical sun, trying to discern some hidden message—a clue as to whether 33 million Sudanese will stop killing each other anytime soon.

We are sneaking into Unity State, the start of Sudan’s pipeline, some 450 miles northwest of the Kenyan border.

Flying into rebel-held southern Sudan from Kenya, you must be prepared for certain compromises. First, the flight is illegal. The central government in Khartoum disapproves of independent visits to its unseen war. Then there is the question of facilities. They simply don’t exist. For almost four hours we drone over a landscape of impressive emptiness—a sea of grass that is burned and reburned by wildfires into a mottling of purplish grays, as if the muscles of the earth itself lay exposed. Later, a huge bruise darkens the western horizon: the famous Sudd, an enormous swamp clogging the flow of the White Nile. When the chartered Cessna finally touches down at a rebel airstrip, the pilot anxiously dumps my bags in the dust and leaves immediately for Nairobi. This is natural. His shiny airplane, a target for government bombers, stands out dangerously in the bleakest liberated zone in the world.

I have come to see George Athor Deng. Deng



BARREN

Desert smothers much of northern Sudan. Since the 1970s, investors have taken what little good agricultural land there is, evicting farmers and herders to grow crops for export. But mechanized farming destroys fragile soils, and millions of acres have been lost to erosion. Commercial farming, says scholar Mohamed Suliman, “rolls like a fireball across the land. . . . Its appetite . . . is rapacious . . . and the only natural direction for it to go is southwards.”

is a Dinka fighter, an SPLA commander of note. And he has promised, via shortwave radio, to show me what oil is doing to his people. He smiles sourly when I tell him what the diplomats say, that oil can bring all the Sudanese together.

“When has the north ever shared anything with the south?” he says of the government oil fields a two-day’s walk across the front lines. “In

the near future we will shut them down. Shut the oil down completely.”

I meet Deng where he spends most of his days, issuing orders from a folding chair under a shady acacia. His headquarters, Biem, is like an engraving from another era—from the journals of Stanley and Livingstone. Stockades of elephant grass surround his crude huts. Food is



mortar oil rigs or shoot at oil company planes. And the Khartoum regime responds by striking back ferociously against local civilians. Government helicopters bought with new oil revenues strafe Dinka and Nuer villages. Sorghum crops are torched. And the dreaded *Murahilin*, Muslim raiders armed by the Sudanese Army, sweep through porous rebel lines on horseback, sowing terror and taking slaves. Khartoum denies that it is targeting noncombatants, just as it has long rejected responsibility for slavery in Sudan; it calls these raids tribal abductions, and says they are beyond its control.

“It is simple,” Deng declares. “The government is depopulating the area to make way for foreign oil companies.”

Deng’s outrage would inspire more sympathy if his own forces weren’t so morally tainted. Traditionally, the SPLA has mistreated as much as defended Sudan’s long marginalized southern peoples. Until the south’s oil wealth helped forge a common cause, various rebel factions—especially the Dinka-dominated SPLA and a variety of ethnic Nuer militias—killed each other mercilessly, often with the encouragement of government bribes. Some commanders have kept civilians malnourished in order to “farm” UN aid. And the movement’s political agenda has never really solidified. The SPLA’s leader, an Iowa State University doctorate named John Garang, claims he is fighting for a secular, unified Sudan (as opposed to the north’s theocracy), yet almost every field commander, Deng included, is gunning for full southern independence.

Knowing what I do about the SPLA, I am prepared to dislike Deng. Compact, scar-faced, blinded in one eye, he promenades around the refugee lean-tos of Biem with a lackey in tow, carrying his chair. Yet there is also an ineffable sadness about him. His entire family—a wife, child, and four brothers—have been wiped out in the current phase of the civil war, which erupted in 1983. Such stupefying losses pervade life in the south. They surface all the time in small, melancholy gestures.

Like the way Deng announces the name of his soldier who is killed, shot down and abandoned, on the ill-fated patrol that I attempt to accompany into the oil fields. “Mayak Arop,” he sighs, waving a gnarled hand over a map of the expanding government oil roads, as if wishing to wipe them away.

precarious. His soldiers scavenge off the land and, when possible, skim UN rations dropped from airplanes for starving civilians. (His troops’ canteens are empty plastic jugs marked “Canada-Aid Soy Milk.”) There are at least 25,000 displaced people jammed into Deng’s territory, virtually all of them Dinka herders fleeing the fighting in the nearby oil fields, and whenever groups of famished refugees trudge through Biem, begging for food, the commander dispatches a marksman to shoot a hippo.

According to Deng—and he is broadly backed up by human rights groups—oil has sparked some of the ugliest fighting Sudan has seen in years. Deng and other SPLA commanders



ENTANGLED

Far from the war, northlanders in town for the weekly cattle market have suffered from inflation caused by high military spending. Many northlanders died when fighting resumed in the 1980s. More recently most of those killed by the government also have been northlanders, recruited or forced to fight for the north.



KIDNAPPED

In the limbo of a Khartoum transit center, ■ Dinka girl abducted from her village awaits return south (right). Stung by charges of slavery,

Sudan's government has allowed hundreds of abducted women and children to be reunited with their families. But thousands remain in the north while abductions continue, carried out by Baggara herders from Sudan's drought-prone west (below). Playing on Baggara-Dinka tensions over pastureland, the government arms Baggara horsemen to ride south with army resupply trains, raiding Dinka villages as they go.



Or, in the way a bowl-bellied Dinka girl stamps out a pretty little dance on a dusty path in Biem, oblivious to the thousands of haunted figures camped in the bush around her.

Or, in the answers to a simple question.

What color is oil?

"It's like cow urine," says Chan Akuei, an old herder at Biem with a belly wrinkled like elephant skin. Government troops have shot his cows, an incomprehensible crime in the Dinka universe. The Dinka adore their cattle. They rarely kill them for meat, and compose songs about their favorite animals. Akuei cannot stop talking about his murdered livestock.

"It is as clear as water," says ■ boy in Koch, a nearby frontline village. He is a member of an ethnic Nuer militia. The last I see of him, he is marching off at dawn to attack an oil road along with hundreds of other rebels—many of them children.

Nyanayule Arop Deng (the name Deng is common among the Dinka) doesn't know the

color of oil. She sits by her skeletal husband, who is dying of kala-azar, a wasting disease that has killed tens of thousands in the oil zone. "All I know is the lights," she says dully. "They appear at night. We don't go near them."

The tower lights of Roll'n wildcat rig number 15 click on at dusk—an unexpectedly pretty sight as the sun drops behind the iron silhouettes of the thorn trees. The quest for oil is tireless, urgent, expensive. It is like a physical thirst—an around-the-clock obsession. Before the evening shift comes on, Terry Hoffman, a sweat-soaked driller from British Columbia, runs one last stand of pipe down into the skin of Sudan.

"Killer bees, cobras, and acid-spewing bugs that give you blisters!" Hoffman hollers over the rig's noisy generator, ticking off the dangers of roughnecking in Sudan. "Boredom's the worst, though. You can't even walk around this place."

Hoffman is a prisoner of his rig. He and his



crew must eat their barbecued chicken and cherry pies, read their e-mail, and lift weights inside a Sudanese version of Fort Apache: a 15-foot-high berm has been bulldozed around the floodlit work site. Heavily armed government troops patrol the perimeter against the likes of George Athor Deng. Deng is doubtless out there tonight, plotting under his tree.

The idea behind rig 15—a small component in a billion-dollar complex of drilling equipment, dormitories, pumping stations, new roads, and prefabricated office buildings at Heglig, Sudan's torrid version of the North Slope—is visionary in its way.

At present, none of the Western energy majors dares to drill in Sudan. Chevron suspended its exploration in 1984 after three of its employees were shot dead by rebels, and pulled out of the country altogether in 1990. (All American companies abandoned Sudan once the U.S. listed it as a supporter of terrorism and imposed sanctions in the 1990s.) Yet today an

improbable mix of engineers from communist China, authoritarian Malaysia, democratic Canada, and Islamist Khartoum have cobbled together an experiment in globalization on the baleful plains of the Sahel. The Greater Nile Petroleum Operating Company, as it is called, pumps 240,000 barrels of crude a day out of a war zone. Two years from now that output is projected to nearly double. It may surge even higher should lasting peace return to Sudan, and the rebels allow French, Swedish, and Austrian companies to explore their concessions in the south.

"All these stories about us pushing out local people to pump for oil? A total lie," says Bill, a rig supervisor with Talisman Energy, the Canadian partner in the Heglig project.

Bill wears cowboy boots and doesn't share his surname. Like everyone else I meet in Heglig, he seems aggrieved. Talisman has come under fire from human rights groups for allegedly turning a blind eye to government atrocities in

the oil patch. (Partly because of this bad publicity, Talisman will later sell its Sudan operation to an Indian oil company.) In response to the criticism, a wary company official in Khartoum lectures me on the value of free markets in reforming oppressive regimes. Supervisors drive me around Heglig in a pickup truck, pointing out unmolested villagers in the savanna. Few of these people are southerners. Most are Baggaras, northern Muslim pastoralists who vie with the Dinkas for grazing lands, and who have come to the oil fields to hack down trees for charcoal.

"TV at home shows these incredible stories—famines and war in Sudan," says Bill. "Well, let me tell you, I've been in a 200-mile radius of this place, and I haven't seen that."

Bill may be willfully blind. But then so are his faraway customers. The only difference is, Bill must walk past a rebel bullet hole in his trailer wall every day and not see it. This is a difficult feat. But a common one in Sudan.

There is no fixed front line between SPLA territory and government-controlled Sudan. No walls. No razor wire fences. No permanent Thorn Curtain. The war is fluid. One army cedes power invisibly to another, and what changes across the no-man's-land are things far subtler and more profound than claims of political control. The round grass huts of Africa give way, slowly, to the square mud houses of desert dwellers. The hot blue dome of the tropical sky recedes behind a veil of white Saharan dust. As I travel north, the 21st century begins to reappear—roads are graded by machines, and human beings once more begin to congregate into towns. Some of these towns have sidewalks. The sight—concrete poured on the ground merely to ease walking—is mesmerizing; a surreal extravagance after the utter desolation of the south.

The oil pipeline rockets north from Heglig and crosses the eerie rock piles of the Nuba Mountains. (See "The Nuba: Still Standing," page 60.)



The pipeline disappears into slums. A cratered highway leads into an enormous traffic jam. Silently, patiently, the drivers advance into a city of waiting. This is Khartoum.

The Nuba people, allied with the SPLA, have been fighting their own war of autonomy against Khartoum for years. A U.S.-brokered cease-fire is in place when I drive through. I see government trucks rolling up into the hills, loaded with satellite dishes. The equipment is meant for “peace clubs” designed to lure the stubborn Nubas down from their mountain strongholds and into areas of government control. “Many of them have never seen television before,” a grinning official explains in the garrison town of Kadugli. “We give them 22 channels, including CNN. Their leaders are very irritated by this.”

The pipeline burrows onward under a mound of raw earth—a monumental tribal scar creasing the barren landscape. Construction began in

1998 and was finished in 14 months by 2,000 Chinese laborers sweating through double shifts. Workers who died in Sudan were cremated on the spot, and their ashes shipped back to China.

I chase the 28-inch-wide steel tube on bad roads. Dilling. El Obeid. Rabak. The northern towns swell, turning into ramshackle mud cities. Two days north of Heglig, the pipeline disappears into slums. A cratered highway leads me into an enormous traffic jam that backs up for miles. Buses nudge through herds of sheep. Donkey carts jockey with taxis so battered they look like the products of junkyard crushing machines. Pedestrians step unhurriedly among the stalled vehicles. Yet no one is angry or abusive. There are no honking horns, insults, threats, or curses.



DISPLACED

Half the nearly four million southerners driven from their homes by war live around Khartoum, in shanties or desert camps (above).

These women, in line for food, have spent so long in the capital they now cover their heads to conform with Islamic law. Robbed of their land by commercial farms, many northerners also end up in Khartoum looking for work. A wedding brings men home to Karima (left), a northern village. After a month or two they will return to the capital or leave for years as migrant laborers in the rich nations of the Persian Gulf.

HIDDEN

Blending into the trees near
Ulin Rom, a Dinka and his cattle
escape attack by government
troops, who avoid the forest
because they fear ambush by the
rebel Sudan People's Liberation
Army (SPLA). If the herder stays
in the forest, he faces another
threat and flies that spread a par-
asitic disease called kala-azar.
Unfenced, it almost always kills.







SLAUGHTERED

Government bombs killed five Dinkas and their herd of cattle near Biem, the only area near the Unity oil fields still held by the Dinka-led SPLA ■ the summer of 2002. Despite international protests, planes have frequently targeted cattle and crops to deprive southerners of food. A Dinka song mourns the destruction: “The birds in the sky are surprised by the way I have been orphaned. The animals of the forest are startled by my skeleton.”

Silently, patiently, the drivers creep forward. They advance, inch by inch, into a city of waiting.

This is Khartoum.

“Please put your notebook away,” advises Asim el Moghraby. “We don’t want any problems.”

El Moghraby and I are perched in a borrowed motorboat, bobbing in the middle of the Nile. I have joined el Moghraby expressly to avoid problems—to admire an overlooked natural wonder of Africa: the meeting of the Blue Nile and White Nile. The two majestic streams, tributaries of the world’s longest river, swirl together in a mile-wide dance of light—one the hue of an evening sky and the other the color of a milky sunrise. Yet Sudan’s troubles are insistent. El Moghraby, a retired University of Khartoum biologist and my unofficial guide in the city, is nervous. Western visitors are relatively rare in the city. And he worries that I will draw the attention of secret

police. We are too close to shoreline government ministries. “The regime is loosening up,” he says apologetically as we chug back to the marina, “but nobody knows how much.”

Change is coming to Sudan, but few know if it is deep or real. The thinking of the small cabal of generals and fundamentalists who run the country is largely opaque. Nevertheless, the virulence of their Islamic revolution began fading even before 1998, when the Clinton Administration launched cruise missiles at a pharmaceutical plant in Khartoum in retaliation for al Qaeda’s terrorist bombings of two U.S. embassies in Africa. Eager to put those years behind them, Sudan’s secretive rulers claim they have expelled some 3,000 foreigners linked with terror groups (bin Laden and Carlos included) and that they have released most political prisoners. Opposition parties have been invited back in from the cold, though they often remain marginalized.

Nubas and Dinkas accost me: “They are taking our children!” they whisper, describing how their young men are yanked off sidewalks and buses to fight for the army.

Driving around Khartoum with el Moghraby—a lean, balding scholar who reminds me of a patient turtle, with his wrinkled neck and watchful eyes that dart behind wire-rimmed glasses—I see a crumbling metropolis of seven million that seems to be fluttering its dusty eyelids after a long slumber beneath the sands. Young couples hold hands on the banks of the Nile, unmolested by the morality police. Flashes of oil money glint off fleets of new Korean-made cars. And freshly painted Coke signs and a new BMW dealership have popped up in the city’s shabby downtown.

Still, it is staggering to think that this insular, puritanical city—with its turbaned Arab rulers, domed mosques, and tea shops blaring pop music—is the capital of the bleeding African south. Yet the war is here too. On a blazing afternoon I visit Wad el Bashir, one of the miserable camps where some of the nearly two million southerners are sweating away their lives in and around Khartoum. Nubas and Dinkas accost me in the maze of dirt lanes. “They are taking our children!” they whisper, describing how their young men are being yanked off sidewalks and buses to fight for the Sudanese Army against their own people in the south. Behind their mud huts I spot my old companion, the pipeline. Its inert presence now seems malevolent.

Popular discontent—and profound war-weariness—is only slightly less palpable among northerners in Khartoum. University students complain about the loss of jobs and political freedoms under the Islamists. Arab businessmen bemoan Sudan’s ruinous isolation. (“Please tell the world we are not all terrorists and bullyboys,” pleads one wealthy trader.) And several middle-class men openly boast of evading the draft—they aren’t buying jihad’s promise of a direct ticket to heaven.

“What you are seeing is the northern front in Sudan’s civil war,” explains a human rights advocate named Osman Hummida, when I share my surprise at the cynicism I find on Khartoum’s streets. “Sudan is not just divided north-south. There is a broader struggle. It is the center against the periphery—a tiny Khartoum clique

against everyone else, including fellow Arabs.”

My tour guide, el Moghraby, is a casualty of this subtler northern war. Bullying his Land Rover through Khartoum’s downtown one day, he points to a drab building and says, “That one’s mine”—meaning the old ghost house where he was detained in 1992, along with his politically active lawyer. In 1995 he was arrested with his wife for producing a documentary film critical of Sudan’s environmental record. He was imprisoned yet again, in 1999, for publicly questioning the country’s oil projects.

Like many disillusioned northern intellectuals, el Moghraby has withdrawn from public life. He has retreated into private enthusiasms—into the past. He takes me one day to see a weathered colonial monument honoring the charge of the 21st Lancers, a once famous skirmish in the British conquest of Sudan in 1898. Wistfully, el Moghraby talks of an older, more cosmopolitan Khartoum of electric trams, midnight cafés, and clean-swept streets. This nostalgia is sad, especially given Britain’s divisive legacy in Sudan.

As a young soldier, Winston Churchill participated in the charge of the 21st Lancers outside Khartoum. British horsemen slammed into the ranks of defending Sudanese troops with such force, he wrote, that “for perhaps ten wonderful seconds” all sides simply staggered about in a daze. The beleaguered citizens of Sudan’s capital know this feeling well. They have endured it for the better part of 50 years. It is not wonderful.

Where is undemocratic, underdeveloped, and oil-rich Sudan headed? For answers I must leave the periphery. I go to the center.

Sudan’s president, Lt. Gen. Omar al-Bashir, almost never grants interviews. Hassan al-Turabi, the intellectual father of Sudan’s Islamist movement, is also not available, having been put under house arrest by rivals in the government. (He has since been locked up in Kober Prison.) So the task of explaining the policies of the secretive National Islamic Front that rules Sudan falls to Hasan Makki, an Islamic academic



CASUALTIES

After two more full days at Juba, in the north, a wounded SPLA fighter is carried to a plane that landed in defiance of a government ban to pick up photographer Randy Olson. The rebel will be flown to the hospital in Lokichale, Kenya. The government routinely denies humanitarian access to rebel territory, the SPLA, for its part, often seizes food.



and one of the regime's leading ideologues.

Makki greets me in a dazzling white djellaba, or Arab robe, in his spacious home. He is a member of the elite "riverine" Arab tribes who have monopolized power in Sudan for years. Like most of Sudan's political inner circle, he is friendly, smart, and chooses his words carefully.

On the war: "It is effectively over, my friend. The south already has lost. Millions of their people have moved up to join us in the north." Ignoring the detail that the refugees have not come by choice, he calls Khartoum "an American-style melting pot."

On Arab-black hostility: "How can there be racism? Look at my skin. No northern Sudanese is a pure Arab. For centuries our blood has mixed with Africans. We are brothers!"

On oil: "It is a blessing. It will hold Sudan together. Before oil, we northerners were tired of the south. Why lose our children there? Why fight for a wasteland? Oil has changed all that. Now our economic survival depends on it."

Regarding the unpopularity of the regime, Makki has little to say. He politely pours me another cup of tea and suggests that I go look at stones.

We have flown, walked, and driven more than 600 miles through Sudan.

The pipeline leads on—tireless and unerring, far more sure of itself in the turmoil of Sudan than I ever will be. Its oil is kept at 95 degrees Fahrenheit, the temperature required for it to be thin enough to flow freely. It tunnels through Khartoum's bleak refugee camps, then slips beneath the Nile. Emerging from the other side, it disappears north into an ocean of light: the Nubian Desert.

There, baking under the sun, are Makki's stones. They are the silent remains of ancient cities and temples.

At a city called Naga, a ruin of great beauty and stillness that juts from the eroding hills east of the Nile, I see a relief carved into an imposing temple wall. It depicts a queen grasping a handful of



STARVED

Without cows or outside aid, Dinkas around Biem ■■■ reduced to eating leaves. First they strip branches closest to the ground, then they climb into the trees (right). Such a diet, supplemented with water lily roots, provides the barest means of survival, leaving the Dinkas malnourished and prone to disease. A home remedy of cattle dung is all a boy has to treat a lice infestation (above). In areas of the south cut off from medical help, diseases eradicated elsewhere—tuberculosis, guinea worm, river blindness—rage unchecked.

small, doomed captives. The queen is recognizably Nubian: Chiseled in pharaonic splendor, she is a mix of Egyptian elegance and full-hipped African beauty. Her prisoners too strike me as dead ringers. They look like the far-flung citizens of Sudan's modern fringe: fierce Beja nomads from the Red Sea Hills—or even Negroid Dinkas or Nubas from the south. Blinking sweat from my eyes, I stare in amazement at this antique blueprint for governance in Sudan—a 2,000-year-old political poster advertising the power of Nile-based elites over the weak periphery.

“Some things never change,” says Dietrich Wildung, head of the Egyptian Museum and Papyrus Collection in Berlin and one of the sunburned archaeologists working at Naga. “The north always thinks itself supreme—Egypt over Sudan, Berlin over Munich, New York over Alabama.”

Wildung, an almost dauntingly effusive man, pads briskly around his digs in a flimsy pair of sneakers, pointing out details on a half-excavated temple that make him exclaim with pure delight.

According to archaeologists, Sudan's northern deserts hide one of the great civilizations not only of Africa but the world. These Sudanic realms—variously known as Nubia, Kush, or Meroë—were no mere appendages of neighboring Egypt, as was sometimes thought. Their intelligentsia created an Egyptian-derived writing system, Meroitic, for a still unintelligible language. And the “black pharaohs” of Sudan and their notorious archers eventually gained such power that they briefly ruled all of Egypt some 2,700 years ago.

Proudly, Wildung shows me his latest discovery: an altar excavated from beneath a fallen wall. Nile gods painted on its plaster-covered pedestal indicate Egyptian influence, and the floral designs are pure Africa—all exuberance, singing colors. Ancient Greece reveals itself too in the classical flourishes on a figurine of the Egyptian goddess Isis. Crouched over a hole in the earth, we behold the unexpected beauty of Sudan's fractured nature, the art of a continental crossroads.



When I leave, Fatna offers me a gift: He dances good-bye in the dust. The flapping of his scrawny arms, the dry snatches of song, seem like a lament.

Can oil dilute the age-old divisiveness of Sudan? The pipeline is my guide. But it is no oracle.

North of the city of Atbara, the steel artery is patrolled by wild-looking men in vehicles mounted with heavy machine guns: *mujahidin*, or holy warriors, guarding the pipeline from being blown up, as it was nearby in 1999. (That act of sabotage was carried out by northern opposition forces in alliance with the SPLA.) The oil squirts across the Red Sea Hills at the pace of a fast walk. Then it races 3,000 feet down to the devastatingly hot Sudanese coast. To the Bashair Marine Terminal. To the end of the line. When I visit the high-tech export facility, a Singapore-flagged tanker is preparing to gulp a million barrels of crude.

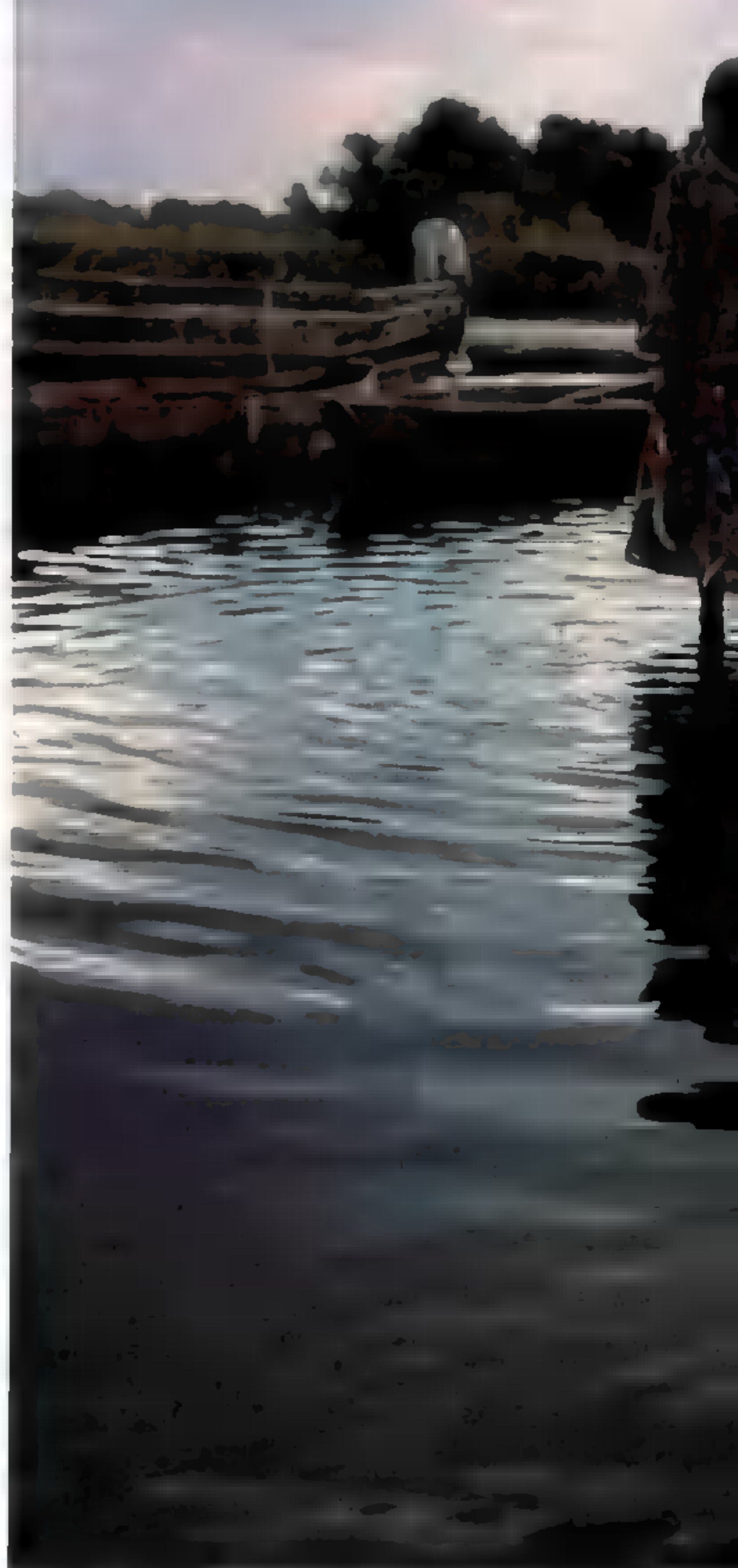
"You are looking at our gateway to the world," a jumpsuited technician tells me grandly in the sleek control room, some 950 miles from the oil wells pocking the savannas of Africa.

I hope he is right. I hope oil helps create a new era of stability in Sudan. I hope it prods international efforts, such as those of U.S. peacemaker John Danforth, to end the terrible civil war. I hope it bribes Sudan's cruel and insulated elites into abandoning selfish power struggles that have wreaked hell on millions of ordinary people. I hope it somehow lubricates relations with Egypt, the regional superpower, which exercises powerful interests in Sudan: Egypt strongly opposes southern independence, fear-

ing that such a development will threaten its access to the vital middle reaches of the Nile. Most of all, I hope Sudan's new oil revenues—more than two million dollars a day—do not end up

WEBSITE EXCLUSIVE

Narrating from his diary, photographer Randy Olson describes life on assignment in war-torn Sudan. View a photo gallery and find resources at nationalgeographic.com/ngm/0302.



stoking what one analyst calls a "perfect war," a conflict waged, at tolerable cost, indefinitely. Hope: a commodity Sudan could use more of, even, than oil.

Near the end of my journey, I camp for a few days in the parched wilderness of the Red Sea Hills. My host is Abu Fatna, an old Beja, a Muslim nomad whose ancestors have roamed the eastern wastes of Sudan for the past 5,000 years. His tent is pegged only 40 miles west of the pipeline, yet his life is as detached from its power and wealth as those of the southern Dinkas dying at the opposite end of the oil trail. Drought has forced Fatna to sell his camels. Saudi hunters have slaughtered all the local wild



SURRENDER

Shuffling through shallows, a southern girl who fled to the government garrison town of Juba eats a foraged mango as she crosses to the island where she sleeps. Sudan's civil war has brought misery to the south and poverty to the north—a military stalemate that devours lives and drains resources. Last year saw the most progress toward peace since war resumed in 1983. The country's best hope may be the recognition that neither side can win.

antelope. He is skinny and poor, and he has only two teeth left in his head. But he still knows which desert stars to travel by. He can still handle a tribal broadsword.

When I leave, Fatna offers me a gift: He dances good-bye in the dust. The flapping of his scrawny arms, the dry snatches of song—these are meant as an honor, though they seem more like

a lament. Driving back to the pipeline, I wonder if this sadness, too, somehow gets pumped out of Sudan. Along with commander Deng's bitter hand-waving over a crude map. Or el Moghra-by's demoralized retreat from the world. Or the terrible absences of so many dead.

So much heartbreak, it seems, gets burned up in Sudan's oil. □

Still Standing



the Nuba



Branded as infidels by Sudan's Islamic rulers, a traditional people fight for their lives.

Fresh from throwing his opponent, a young Nuba wrestler is blessed with ash to mark his victory. Half a century ago, a robust champion was hoisted onto a teammate's shoulders. Hunger and sickness caused by government attack and blockade in Sudan's civil war have shrunk the Nuba's physique. Yet they have endured to see a ceasefire in the Nuba Mountains—and fragile hope for their culture's survival.



© GEORGE HERRING, MAGNUM PHOTOS

By Karen E. Lange Photographs by Meredith Davenport

NATIONAL GEOGRAPHIC WRITER

Bearing loads home the only way they can, Nuba women walk through the hills where their people have often fled to escape the civil war, abandoning the surrounding plains. In 1985 the rebel Sudan People's Liberation Army (SPLA), based in the south, infiltrated the Nuba Mountains, the Nuba homeland in central Sudan. Long discriminated against by the north's Arabized, Islamic majority, many Nubas—members of a minority that clings to indigenous traditions—joined the rebels. In response the government declared all Nubas the enemy; militias surrounded the mountains, occupied the towns, and terrorized the plains, burning villages and farms, and raping, killing, and abducting civilians. Seeking refuge in the hills, the Nuba could not grow enough to eat. Meanwhile Khartoum banned humanitarian aid flights, hoping to starve Nubas out. Tens of thousands died; hundreds of thousands were forced into government "peace camps." More than a million survive, 350,000 in rebel areas. Among survivors, long-relegated women relish a gift of sesame oil, prized for the gleam it gives their skin (*toppsithi*).

WEBSITE EXCLUSIVE

Learn how photographer Meredith Davenport gained entry into exclusive rebel territory in an online interview at [nationalgeo.com/2011/08/20110820nuba](http://nationalgeographic.com/2011/08/20110820nuba)

NEAR KAUDA, OTORO HILLS





HILLS



Where Arab Meets African

The battle for the Nuba Mountains is strategic—they border Sudan's oil pipeline. It is economic—below the rocky hills lies some of the country's most fertile land. And it is cultural. Journalist Oswald Iten calls the Nuba homeland "the front line between . . . two ways of life." The Nuba, diverse

tribes who share a common culture, form an island of black Africa in the Arab-dominated north. Most Nubas speak Arabic, and about half are Muslim, yet Suddinese Arabs despise their continued faith in traditional healers and ritual customs like *namay*, beer drinking, and female wrestling.



©SARAF JAMUS, LIMON HILLS

Holding Out Steeling himself for the larger struggle, a Nuba rebel brandishes an automatic weapon as he dances in the victor's circle after wrestling. To rally a devastated Nuba civilians in rebel territory, the SPLA imposed strict discipline on its fighters, offered a measure of democracy, and encouraged a cultural revival. Traditionally the Nuba saw no dilemma in having their bodies, ~~used~~ as they were unfit or sick. At a ceremony welcoming the Nuba SPLA commander, a woman (below) took off her clothes

LEWERI, LIMON HILLS





...continued herself with mud. The freedom to continue such customs has kept many
Nubas in the traditional style food in medical care. Falling to the ground in grief
today, a Nuba mother sobs over the grave of her three-year-old baby, who died
the night before without seeing a doctor. A sorghum stalk is placed into the pit—the
newborn's last ration. "People die like flies," a wartime song laments. Born near a
hospital, and the infant is lucky (said). Treated for diarrhea, he will go home alive.

GERMAN EMERGENCY DOCTORS HOSPITAL. OTORO HILLS



Enduring Spirits Drunk onorghum beer, Nubas at a peasmaking festival form a bulking conga line, their bodies decorated with bits of fur, beads, insect—whatever they can find. “Then there suddenly a hundred people dancing in a frenzy,” says photographer Meredith Davenport. “The mayhem reached its zenith with men and women running toward a hill to wrestle. Three or four groups rolled around in a cloud of dust, laughing—women were taking men down to the ground.” Later, during a more sober ceremony, the clan *kujurs*, or medicine men, symbolically buried

ACHIRUN, LIMON HILLS



the preceding year's problems in hopes of a better future. In 2001 a government offensive almost wiped out the Nuba. Last year a U.S.-brokered cease-fire ended fighting in the Nuba Mountains, brought UN relief flights, and led to negotiations for peace for all of Sudan. But the status of the Nuba has yet to be settled. Will they, like the Dinka, have a chance at autonomy and a vote on their future? Having held out since 1985, the Nuba now face new challenges: How to manage outside aid without losing their self-reliance and achieve peace with the right to be themselves. □





Searching for
Sacagawea

*We know little of her
life story. That hasn't
stopped people from
telling it.*



*Saugonen slept here
along the Missouri River
near Montana's White
Cliff. From April 1805
to August 1806, the
Native American man
traveled with Lewis and
Clark on their landmark
journey west—and
achieved nothing of fame.
Yet no one knows
what she looked like; no
words of hers remain.*



By Margaret Tallon
Photographs by Chris Jagers
SENIOR EDITOR
Art by David Green



After meeting in the
waters of the Missouri
River by boat, Lewis
and Clark needed horses
to cross the West.
The journey led them to
help and hire, come
with her own people,
the Shoshone, or Snake,
Indians.

"The circumstance of the Snake Indians possessing large quantities of horses, is much in our favour, as by means of horses, the transportation of our baggage will be rendered easy and expeditious over land." — Meriwether Lewis



M

AY 14, 1805, started off auspiciously for the Lewis and Clark expedition, but by evening a gusty wind was blowing along the Missouri River, threatening disaster. It was late afternoon when a sudden squall nearly capsized one of the boats, the white pirogue that carried the most vital instruments, trade goods, and papers—"in short," wrote Meriwether Lewis, "almost every

article indispensably necessary to further the views, or insure the success of the enterprize."

At the helm of the pirogue, alas, was Toussaint Charbonneau, the French-Canadian fur trader who served as an interpreter for the expedition. Charbonneau had an unfortunate tendency to panic in a crisis, which, coupled with the fact that he couldn't swim, made him, in Lewis's estimation, "perhaps the most timid waterman in the world."

Lewis and Clark themselves were stranded on shore, reduced to shooting into the air in a futile attempt to attract the crew's attention. The waves were mounting higher, the boat was filling to its gunwales, and Charbonneau, who was "crying to his god for mercy," had "not yet recollected the rudder." Lewis was about to hurl himself into the river when it occurred to him that swimming the 300

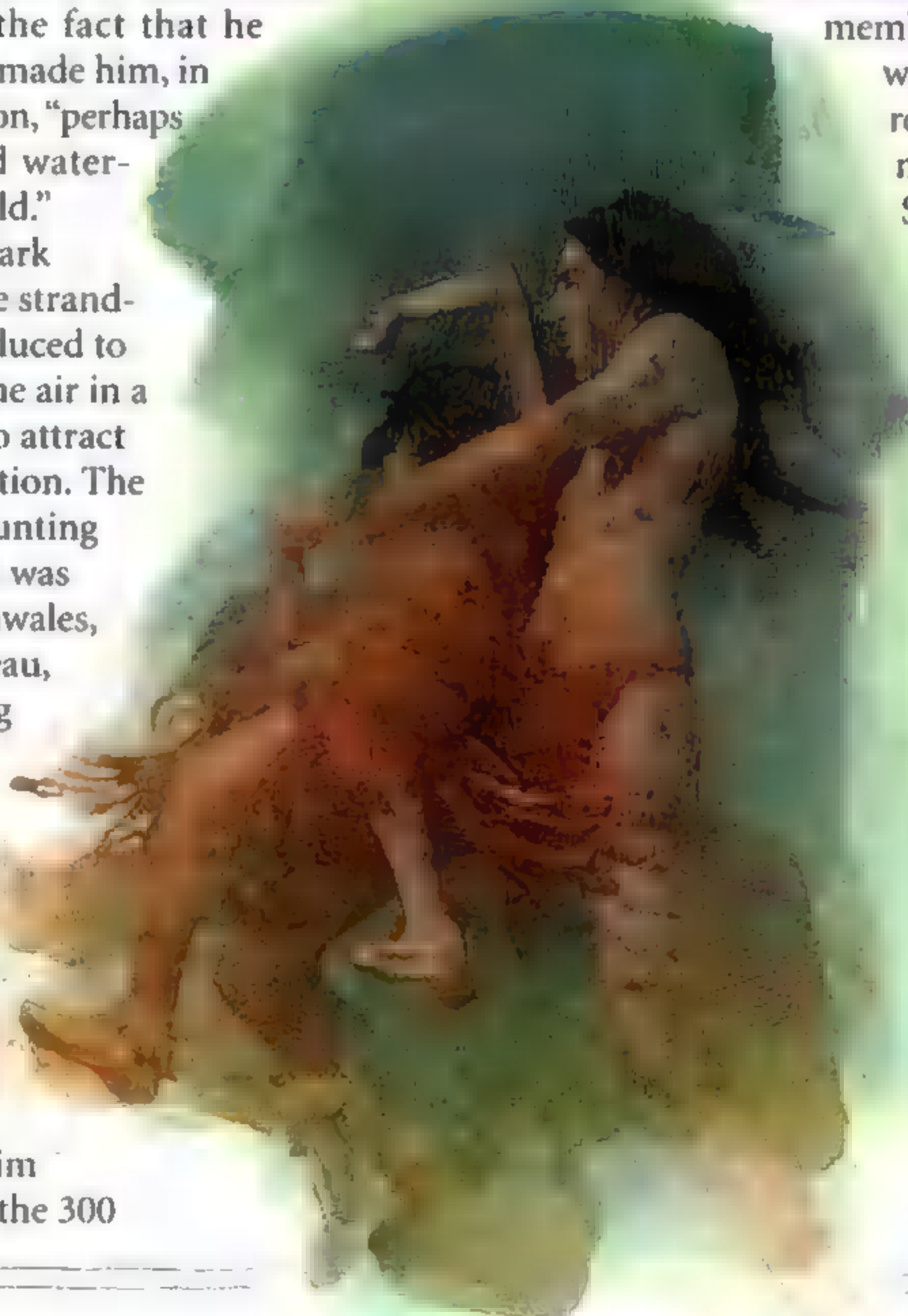
yards to the boat in freezing, turbulent water would be "madness." To convince the petrified Charbonneau to do his duty and take hold of the rudder, another man on board the pirogue finally threatened to shoot him.

Amid all the shouting and gunshots and waves, however, there was one

member of the expedition who proved calm and resourceful: Charbonneau's teenage wife, Sacagawea, the only woman in the party.

Though no one seems to have instructed her to, Sacagawea reached into the water and fished out the articles that were swiftly floating away from the boat. A day and a half later, with most of these precious goods dried and repacked, Lewis realized the expedition had averted disaster.

"The Indian woman," he wrote in his journal on





May 16, "to whom I ascribe equal fortitude and resolution, with any person onboard at the time of the accident, caught and preserved most of the light articles which were washed overboard."

It is one of those rare but powerful moments in the journals that make you long to know more about this woman whom we recognize mostly as a sturdy figure of American mythology—a face on a coin. The very sketchiness of our knowledge has permitted novelists, feminists, and Native American tribes with dueling claims to project what they wish upon Sacagawea, to see her as a metaphor more than a human being. But who was she, really?

There was no likeness made of Sacagawea in her lifetime, and there is nothing left that belonged to her. The glimpses we are allowed of her in the expedition journals are all through the eyes of men to whom much about her must have been utterly opaque. And yet through the journals we know more about Sacagawea than about almost any other Indian woman of her time.

Lewis and Clark first met Sacagawea when she was a girl of about 17, pregnant with her

Captured as a child by a Hidatsa raiding party (left), Sacagawea became the teenage bride of a fur trader named Charbonneau. In April 1805 the couple headed west with Lewis and Clark, but two months later Sacagawea fell gravely ill. Clark, protective of the new mother, treated her with bloodletting (above).

first child. It was November 1804, and the Corps of Discovery, as the expedition was known, had arrived among the Mandan and Hidatsa Indian tribes on the upper Missouri River, in what is now North Dakota. The explorers planned to winter there among these agricultural tribes known to be friendly to whites, tribes whose earth lodge villages—dotted with gardens of squash, beans, sunflowers, and corn—made up a conurbation that was larger than St. Louis at the time.

From the age of about 13 Sacagawea had lived with the Hidatsa near the confluence of the Missouri and Knife Rivers. The place is now a national historic site, and one day last summer I spent some time there trying to reimagine Sacagawea's world. None of the



original earth lodges remain, but one beautiful replica helps tune the senses to that distant time. The lodge's interior is spacious and cool, and smells pleasantly of hide and smoke. Light streams through the single hole in the earth-and-willow-branch roof like a golden column.

With me that afternoon was Amy Mossett, a Mandan-Hidatsa from New Town, North Dakota, and an expert on Sacagawea. Thin and elegant with a cascade of nearly waist-length

black hair, Mossett is something of a celebrity as a Sacagawea stand-in. Her image appears in travel brochures and on billboards promoting tourism—an uphill battle in North Dakota, among the least visited states in the country. She has lectured and told stories about Sacagawea everywhere from kindergarten classrooms to convents to a biker convention.

On a bluff above the narrow gray-green Knife, Mossett and I look out over shallow,





*From "The History of
the Oregon and Snake Rivers
Country from its first
discovery by Lewis
and Clark, East of the
Rockies Indian war a
frequent war - and meal*

SARAH LEEN. IMAGE COLLECTION

bowl-shaped indentations in the ground that are the only suggestions of the earth lodges that once stood close together here. (So close, in fact, that smallpox spread rapidly when it struck here in the 1830s.) Around us the ground is strewn with shells and bleached bits of animal bones. Even on this warm mid-summer afternoon, the prairie wind feels powerful, rattling the historical placards, riffing the surface of the Knife, keeping up a steady sibilance in the cottonwood leaves. It carries the scent of wild mint and prairie roses.

"This is where I feel closest to Sacagawea," says Mossett, who likes to wander around here by herself and think about where, exactly, Sacagawea might have lived on this land. Sometimes, Mossett says, she can almost see her walking along the river, peering up at the sky and spotting eagles.

It has been customary to describe Sacagawea as a slave of the Hidatsa, sold in marriage to Toussaint Charbonneau. But terms like "slave" and "sold" can be misleading. She was certainly a war captive, kidnapped from the Shoshone, the tribe into which she had been

born, by a Hidatsa war party some four years before Lewis and Clark showed up. But when present-day Hidatsa such as Mossett object to the term "slave," they have a point, says historian Carolyn Gilman.

"Plains Indians did have a type of slavery, but it was different and more ambiguous than the kind practiced in the American South," says Gilman, curator of the National Lewis and Clark Bicentennial Exhibition, which is being organized by the Missouri Historical Society. "A onetime slave could be adopted by a clan, for example, and his or her status could change. It was a more fluid identity."

It's also hard to say definitively that Sacagawea was "sold" to Charbonneau. As Gilman points out, "Euro-Americans observing Indian weddings often talked about the women being 'sold,' mistaking the exchange of gifts between the families for purchases." Moreover, in the early 19th century there was a great deal of intermarriage between white (especially French) fur traders and Indian women, and these alliances generally conferred some advantages on the woman. "That may



have changed over time as tribes got more acquainted with white society and more contemptuous of it," says Gilman. "But in Sacagawea's time being a trader's wife was still a mark of status."

In any case, Euro-American explorers, Lewis and Clark included, tended to take ample note of how hard Indian women worked while overlooking the power they wielded. The Hidatsa, for example, was a matrilineal society in which women owned the earth lodges and gardens—this at a time when married Euro-American women could not own property in their own name—and men moved into their mothers-in-law's lodges when they married.

But while marrying a trader might have been a good move in general, Charbonneau may not have been a great catch. He has the sort of shabby reputation that seems impervious to revisionism, though in fairness it may owe something to blustering Francophobia. Gary Moulton, editor of the definitive edition of the Lewis and Clark journals, notes that historians have portrayed Charbonneau as

In August 1805 the expedition entered the lands Sacagawea had known growing up. There, joyfully, she recognized the Shoshone chief as her own brother. She hadn't seen him since her capture five years earlier.

"a coward, a bungler, and a wife-beater." Clark recorded that Charbonneau hit Sacagawea on at least one occasion—along with the fact that he upbraided him for doing so.

There aren't many occasions in the journals when Sacagawea attracts the captains' notice, but those that do tend to be dramatic moments rendered in characteristically laconic prose and decidedly unfussy spelling. In February 1805, at the fort the corps had built for itself near the Mandan and Hidatsa villages, Sacagawea "was delivered of a fine boy," Captain Lewis recorded. "It is worthy of remark that this was the first child which this woman had boarn and as is common in such cases her labor was tedious and the pain vilent." A French-Canadian trader named

"She instantly jumped up, and ran and embraced him . . . After some conversation between them she . . . attempted to interpret for us, but her new situation seemed to overpower her, and she was frequently interrupted by her tears."

Nicholas Biddle

EXPEDITION CHRONICLER

René Jusseume administered a tribal remedy for speeding up labor—a small portion of a rattlesnake's rattle. "Whether this medicine was truly the cause or not," Lewis noted, Sacagawea "brought forth" Jean Baptiste Charbonneau within ten minutes.

The Corps of Discovery set out from its winter quarters on April 7, 1805. Less than two months after giving birth, Sacagawea gathered up her infant son and embarked with her husband on a roughly 5,000-mile, 16-month journey. Contrary to her romanticized image, however, Sacagawea was not the expedition's "girl-guide." On a few occasions in Shoshone country she recognized features of the landscape and was able to reassure the captains that they were heading in the right direction. But most of the territory they passed through was as unfamiliar to her as it was to Lewis and Clark.

Still, in ways both large and small Sacagawea proved herself an asset. Throughout their travels she supplemented the men's diets with wild artichokes and other edible plants she found and dug up. Lewis thought that "our epicures would admire" the root called the white apple. "It would serve them in their ragouts

and gravies in stead of the truffles morella."

One of Sacagawea's greatest contributions was her mere presence, which seems to have disarmed potentially hostile tribes along the way. As Clark wrote, "The wife of Shabono our intepreter we find reconsiles all the Indians, as to our friendly intentions a woman with a party of men is a token of peace."

In mid-August, when the captains met with the leaders of the Shoshone and called upon Sacagawea's services as a translator, the journals record one of those fortunate coincidences you usually forgive only in beloved movies from childhood. Sacagawea, who spoke Hidatsa and Shoshone but neither English nor French, was to translate the Shoshone chief's words into Hidatsa for Charbonneau, who was to translate into French for a member of the corps named Labiche, who would translate into English for the captains. They were just about to begin this unwieldy relay when Sacagawea suddenly "jumped up, and ran and embraced" the Shoshone chief, "throwing over him her blanket and weeping profusely." He was, of all people, her long-lost brother.

Sacagawea's reaction on this occasion surprised Lewis, who had written her off as an inscrutable "squaw" of little feeling. Clark was different. Popular historical novels and plays about the expedition written in the 20th century hint at a romantic (though properly sublimated) attraction between Sacagawea and one of the captains, usually Clark. There is no evidence whatsoever for that scenario, and yet it does seem fair to say, even at this distant vantage point, that a genuine fondness developed between Sacagawea and William Clark. He had a nickname for her—Janey—and doted on Jean Baptiste, whom he called Pomp or

Pompy or “my little danceing boy Baptiest.” For her part, Sacagawea gave Clark a Christmas present of two dozen white weasel tails.

“Clark protected her,” says Amy Mossett. “He put her out of harm’s way during a flash flood early on. She and her husband and son slept in the same tent as the captains for her protection. I think she was fond of William Clark in the way a younger sister is of an older brother who looks out for her.”

On the return voyage, just a few days after leaving the Charbonneau family at the Mandan villages in August 1806, Clark wrote a letter to Charbonneau that is remarkable for its openness of heart toward companions of the road he seems truly, already, to be missing. In it he regrets not having compensated Sacagawea for her services and offers repeatedly to pay for the education of “my little” Jean Baptiste. The child was then 18 months old, and Clark regarded him, he wrote in his journal, as “a butifull promising Child.” (This offer he eventually made good on: Jean Baptiste was educated in St. Louis

at Clark’s expense and went on to become the traveling companion of a European prince.)

“I think the baby was an important bond,” says Mossett. “You can’t be with a child every day from the day he was born and not develop an attachment. When you’re tired, so weary, way out there in the unknown, and you don’t know who or what you’re going to encounter next, a little child coming up to and smiling or laughing or even just looking at you, it would pick up your spirits, it would soften your heart. It would remind you of why you’re doing this—for the future.”

Of all the episodes in which Sacagawea plays a part, there is only one in which she expresses a longing of her own. One afternoon at Fort Clatsop,



Crossing the Bitterroot Range in September 1805, the expedition fought sudden snow and rough terrain for 11 days. Food ran so low they had to kill and eat three colts.



in what is now Oregon, Captain Clark announced that he would be taking a party out to the coast to see a beached whale. He wrote, "The last evening Shabono and his Indian woman was very impatient to be permitted to go with me, and was therefore indulged, She observed that She had traveled

a long way with us to See the great waters, and that now that monstrous fish was also to be Seen, she thought it verry hard that She Could not be permitted to See either (She had never yet been to the Ocian.)"

There is no record of what Sacagawea said or felt when she saw the great waters, but the moment is rich still. If she were a character in a novel, it would be the first hint of an inner life to which we'd soon be admitted in full. In Sacagawea's story it is the deepest insight we get.

After the 21 months in which Sacagawea's story intersects with that of the expedition, she disappears almost entirely from our view. The best evidence we have suggests that she died in her mid-20s at Fort Manuel on the Missouri

"I have been wet and as cold in every part as I ever was in my life, indeed I was at one time fearfull my feet would freeze."

—William Clark

McKenney caused the
dark blizzards when
she was only about 17
years old, enduring
bitter cold and night
walking her narrow
trails while carrying
her seven-month-old
son. Her feat, how-
ever, is not mentioned
in expedition journals.





*"She observed that She had traveled a long way with us to the
fing out waters, and that now that now it was felt was also the
Saw, she thought it very hard that She could not be permitted
to remain." She "wa then free indulged." —William Clark*

River shortly after giving birth to a daughter, Lisette. A year later, when Charbonneau was presumed dead (incorrectly, as it turned out—he lived into his eighties), Clark became Lisette's guardian. But there is no record of the girl after the age of one, and most historians believe she died very young.

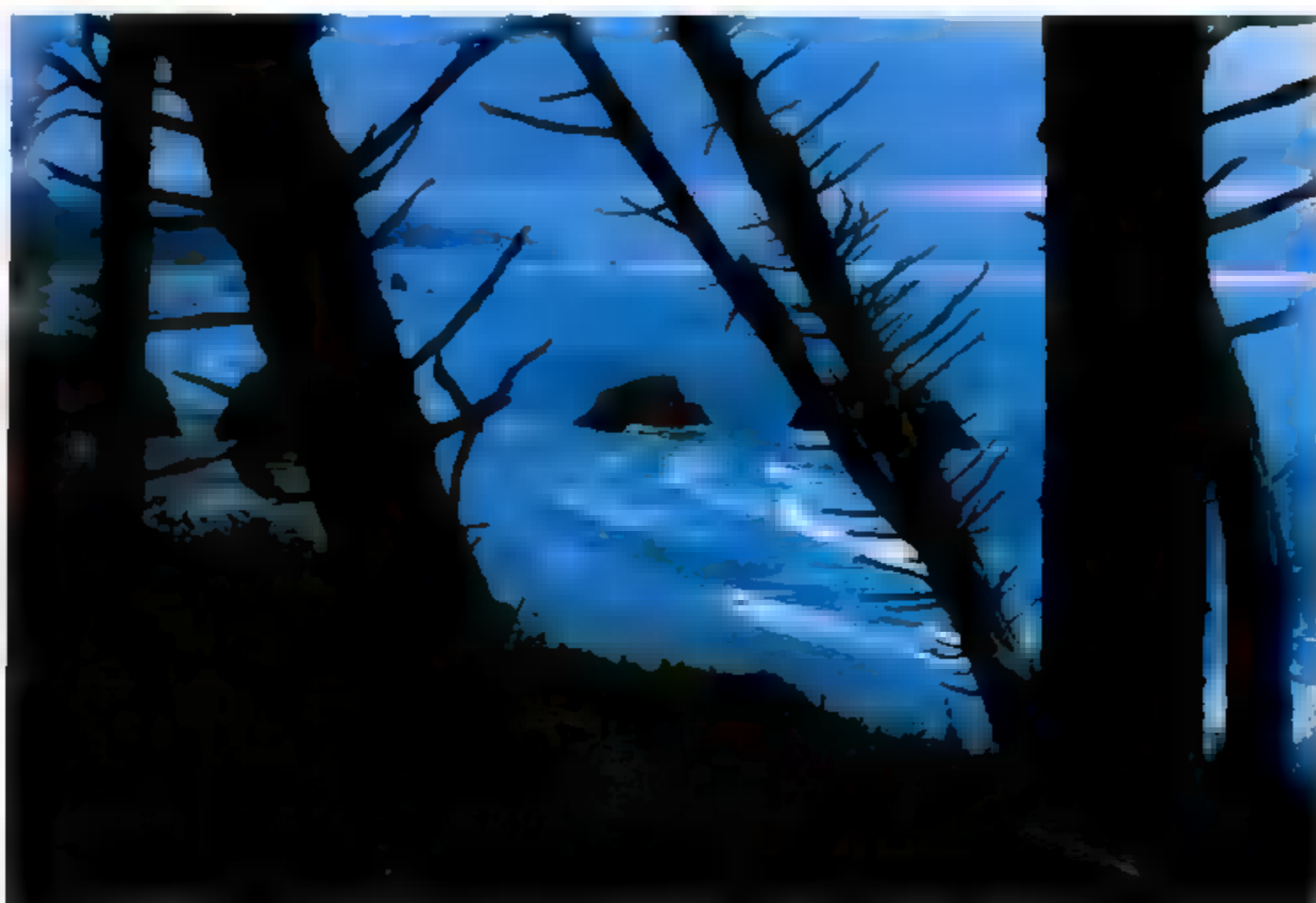
Today there are reportedly more statues of Sacagawea than of any other American woman. Many of them were erected early in the last century with the support of local women's clubs and suffragists like Susan B. Anthony. Several of these monuments—like the lovely one in Portland, Oregon's Washington Park in which Sacagawea resembles a winged victory—make her look older than she was during the expedition, and grander, not a teenager dragged along but a woman who led.

In the hundred years or so after the expedition Sacagawea was nothing like the icon she has since become. The journals languished mostly unread, and there was little to remind Americans of Sacagawea's contributions to a

party of discovery that had, in any case, been overshadowed by the legends of other 19th-century frontiersmen. It was the suffragists, on the lookout for a folk heroine, who rediscovered her. In their portrayals Sacagawea was both an Indian "princess" and a patriotic American. With a little rhetorical exertion, her services to Thomas Jefferson and his vision could be fashioned into an argument for rewarding all American women with the vote.

For many years after her rediscovery, most of the white Americans who wrote about Sacagawea seized upon her as the archetypal "good Indian," one who, like Pocahontas, had aided white men. But in the past couple of decades, and especially for Native Americans, Sacagawea has become a different sort of symbol: a reminder of the extent to which the Lewis and Clark story is also a Native American story. The expedition was, as the historian James Ronda has written, not a "tour of discovery' through an empty West" but a "diverse human community moving through the lands and lives of other communities." Lately, historians have taken to studying the expedi-

tion's mutually informative encounters with native populations and have been more interested in Lewis and Clark as pioneering naturalists and ethnographers than as standard-bearers of manifest destiny. At times this has meant paying less attention to Sacagawea, taking pains not to focus on her as the token Indian presence in the story. "For a long time, Sacagawea was representative of all native people," says Ronda. "A lot of folks





seemed to think, If I mention her, I don't have to mention other native people. I've done my job."

But if you think of her as the native informant closest to Lewis and Clark, then she acquires a new symbolic significance. "I see her as a source of pride for all the tribes," says Amy Mossett. "I know of at least seven tribes that have oral traditions about her or someone like her. I see that as a sign of their really wanting to have some connection to the woman who went on the journey with Lewis and Clark."

For some Native Americans, disputes about Sacagawea's life and legacy—where and when she died, even how to spell and pronounce her name—are of far more than academic interest. For the 400 or so remaining Lemhi Shoshone, who live on a reservation in Idaho, the connection to Sacagawea is one thread on which to hang their hopes for federal tribal recognition and a return of the ancestral lands they say were stripped from them. For the Wind River Shoshone in Wyoming, the connection to the woman they insist is "Sacajawea" (their spelling) and who died on their reservation (most historians dispute this) could anchor them in the Lewis and Clark story, if only they could get people to believe she's really buried there.

Amy Mossett sometimes wonders why

She must have heard the waves before she saw them, finally glimpsing Oregon's shore (opposite) and beached whale bones (above) in January 1806. In the space of a year Sacagawea had given birth, found her kin, and walked halfway across a continent. Her fate is a mystery, yet her legend lives on as pathfinder, feminist icon, and Indian heroine.

Sacagawea didn't stay behind with the Shoshone when the expedition met up with the band headed by her brother. For Mossett the fact that she did not means that Sacagawea had come to feel more like a Hidatsa than a Shoshone. For Carolyn Gilman it suggests that "her experiences may have made her one of those people permanently stuck between cultures, not entirely welcome in her new life nor able to return to her old."

I like to think there was another reason Sacagawea did not stay behind: because by then she wanted to go on—that she, too, had been seized with curiosity about what came next, and where the journey would take her. □

WORTHY EXCLUSIVE

See Sacagawea on the giant screen in National Geographic's new large-format film, *Lewis and Clark: Great Journey West*. For information go to nationalgeographic.com/lewisandclark.

NATIONAL
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EXPLORATION



GRANTED

Theunis Piersma
Evolutionary biologist
Northwestern Australia

"I find it fascinating that these shorebirds can jump from one extreme climate to another with only one piece of clothing and one body."

Icebox to oven: Arctic nesting shorebirds adapt to the intense heat of tropical Australia

Birds That Go to

Mired in their work, researchers Zoe Car, Petra de Goelj, and Anita Koolhaas (left to right) sieve hot mud on tidal flats of Roebuck Bay to tally invertebrates, an essential food for shorebirds.

Extremes

Waders called knots must gorge to put on fat from January to May i



By John L. Elliot

NATIONAL GEOGRAPHIC SENIOR WRITER

Photographs by Jan van de Kam

When shorebirds called knots fly south for the winter, they face an epic migration from their Arctic breeding grounds. Different populations of these far-flung members of the sandpiper clan

disperse to distant havens such as Great Britain, West Africa, even Tierra del Fuego.

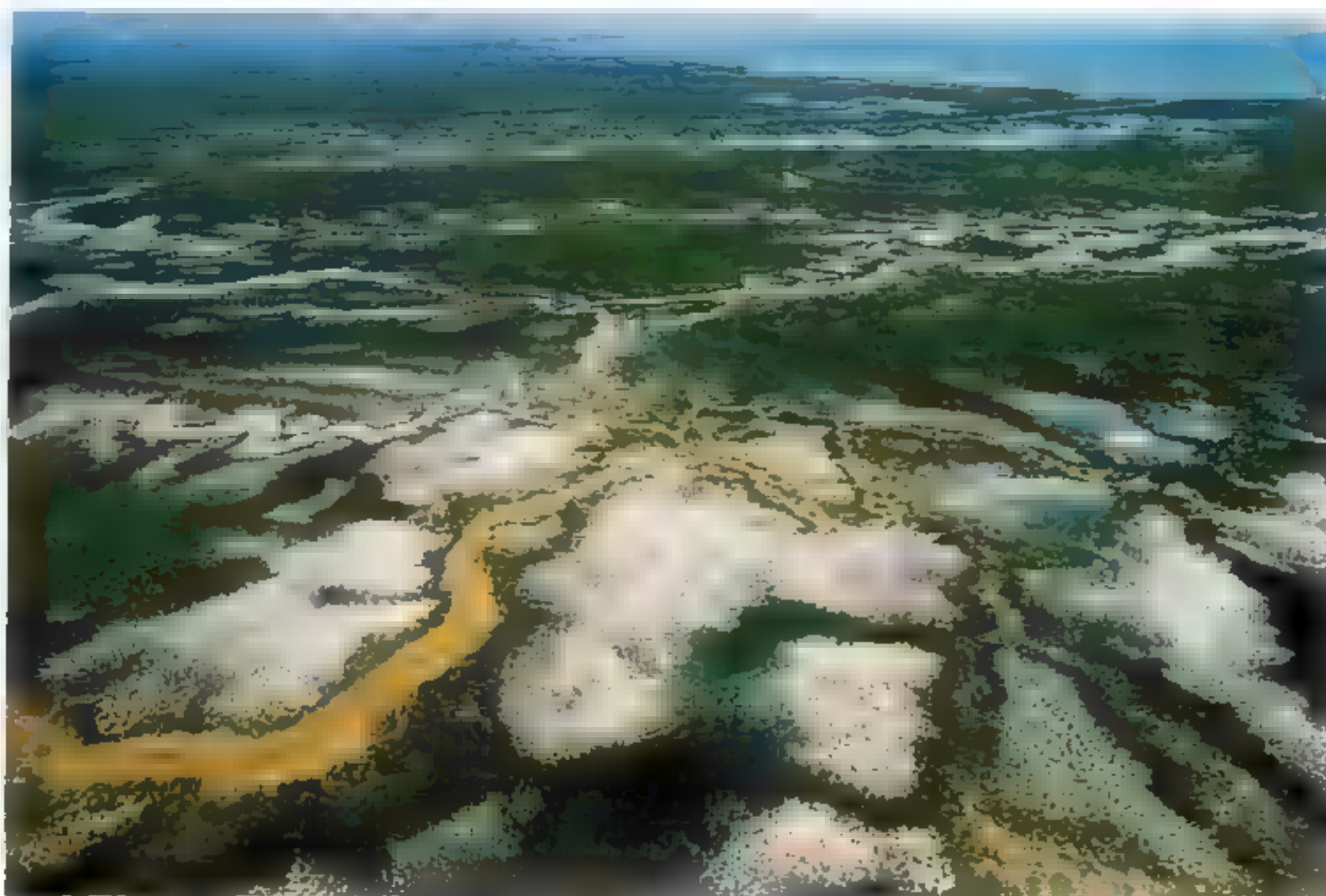
Most shorebirds must travel far to find suitable winter feeding grounds. But knots are marathoners, overflying vast

stretches of unsuitable terrain while seeking coastal tidal flats that they need for food.

One group of knots wings 7,500 miles from the Siberian Arctic to Roebuck Bay on Australia's northwestern coast. Theunis Piersma, an evolutionary biologist with the Netherlands Institute for Sea Research, investigates how the knots cope with the oppressive austral summer, a hemisphere away from Siberia.

About 170,000 shorebirds a

Feeding near a mudskipper (above, right), a great knot fluffs its back feathers to cool off. Great knots and red knots flock to Roebuck Bay to gulp mollusks in the wet season, when nutrient-rich streams (left) feed the bay.



Australia, staging ground for their 7,500-mile migration to the Siberian Arctic.



year migrate to Roebuck Bay, including the two species studied by Piersma and his colleagues: red knots and great knots.

“From February through April the bay is distressingly hot and humid,” says Piersma. “We think that Arctic-breeding shorebirds must find these conditions extremely difficult.”

How hot are the knots? Their body temperatures can reach well above 100°F. They’ll pant and raise feathers on their backs, exposing skin so heat can dissipate. The birds often wade in shallow water to shed heat. But nothing is cool at Roebuck Bay.

“When the tide comes in, you expect the water to give you relief when it flows around your

ankles,” says Piersma. “Quite the contrary—it’s as if somebody poured warm coffee around your feet.” The water can exceed 90 degrees.

Paradoxically, the knots make things worse by simply fulfilling their purpose: to get fat. When they depart for the Arctic, they first fly 3,400 miles in a few days to lay over on the coast of China. So in Australia they must fill their energy tanks to the brim by gorging on mollusks and other invertebrates. That means building up muscle and putting on fat, which makes it even harder to lose heat.

In Roebuck Bay, Piersma and his team studied how knots prepared for their return trip to the Arctic. They attached color


THE PROJECT

TIME: FEBRUARY-MAY

PLACE: ROEBUCK BAY, AUSTRALIA

GOAL: LEARN HOW KNOTS ADAPT TO DRAMATIC CLIMATE CHANGES

TEMPERATURES: NEAR 100°F

ESSENTIAL  **TOOLS:** NETS, BIRD BANDS, TRANSMITTERS, HOVERCRAFT, AUTOMATIC RADIOTRACKING STATIONS

DANGERS: DEEP MUD, BOX JELLYFISH

bands to the legs of more than a hundred birds for visual tracking. They also tagged the birds with numbered metal rings to identify them if recaptured later at Roebuck Bay. With birds in hand they used ultrasound to measure stomach and flight muscles. They examined the birds as they changed from winter plumage to their reddish summer breeding coats, which



“Catching the birds can traumatize them. We don’t take longer than 30 to 60 seconds, and we always cover them quickly to give them shade.”

THEUNIS PIERSMA

FIELD DISPATCH AUSTRALIA



indicates migration readiness.

The team attached radio transmitters to 25 great knots and 23 red knots, then tracked the birds with handheld receivers and with 14 automatic radiotracking stations around the bay. The receivers collected more than 5.5 million bits of data.

In some cases they recorded virtual electronic diaries of individual knots. One great knot was captured on March 4 in fine condition, already showing 90 percent of breeding plumage. Upon release he stayed near the beach where he was caught. "He left on March 29, one of the first radio-tagged birds to migrate," says Piersma.

But red knots—slightly smaller than their cousins—were stragglers. "One was with us a long time," Piersma recalls. It departed on May 7. "Such a

late migration leaves the red knots only four to five weeks to arrive in the Arctic for their short breeding season. Great knots take about eight weeks to make the journey."

Knots can't build up their reserves for the trip without Roebuck Bay's bouillabaisse. But its marine life is threatened by Broome, a center for tourism on the bay's edge. Beachgoers already disturb roosting shorebirds. Piersma and his colleagues have recommended ecological management rules for the bay—"to help people and their avian fellow travelers coexist for a long time to come." □

WEBSITE EXCLUSIVE

Want to know more about knots? Check out our listing of websites and resources at nationalgeographic.com/ngm/0302.



Knots get hot when captured in the heat, so Piersma's team works fast and prepares a net to be fired by mortars (opposite). The net swoops over the birds (below). Then the team gathers knots and takes them to a shady spot for study. Researcher Phil Battley (above) examines a red knot changing into breeding plumage. This red knot subspecies has recently been named *Calidris canutus piersmai* in honor of the study leader.



DAWN IN THE DEEP

A handful of scientists and filmmakers hatched a plan to show the bizarre world of **HYDROTHERMAL VENTS** as it's never been seen before. They took a huge IMAX camera and 4,400 watts of light to the bottom of the sea—then flipped the switch.

BY RICHARD A. LUTZ

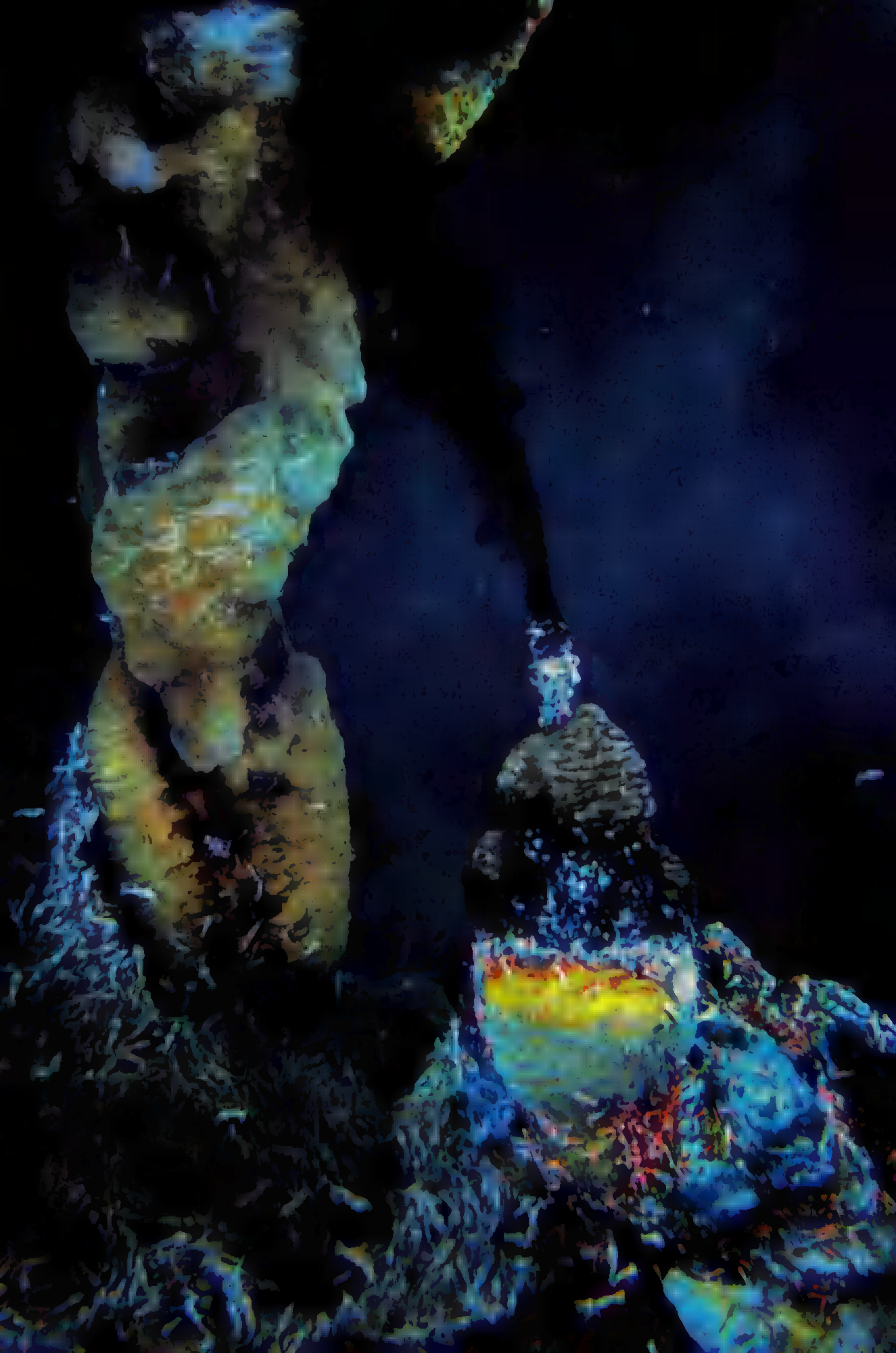
PHOTOGRAPHS BY STEPHEN LOW
PRODUCTIONS

AND EMORY KRISTOF

CONTRIBUTING PHOTOGRAPHER-IN-RESIDENCE

Caught in the act, a "black smoker" vent 11,500 feet deep belches out water heated to 600°F. By morning below the Atlantic seafloor, when this plume hits the cold sea, metal sulfide crystallizes and forms mineral chimneys, harbors for bacteria and other creatures.





Peering through the porthole of a submersible is like looking at outer space with a flashlight. You can't see much. But rigged with high-intensity movie lights, a sub becomes a deep-sea Hubble, revealing such eccentric beauties as the jutting spires of a sulfide chimney (right) or spiny brisingid sea stars combing currents for food. Along with the National Science Foundation and Stephen Low Productions, a team of scientists is helping create an IMAX format film to show in unrivaled detail the riches of hydrothermal vents—ecosystems that may hold clues to early life on Earth.



In the pitch-black world of a deep-sea vent, life is driven by chemosynthesis: Microorganisms like bacteria and archaea convert the chemicals from vents into body mass. At a vent field on the Mid-Atlantic Ridge, hordes of translucent shrimp frantically graze on these microorganisms. The shrimp, dubbed

Rimicaris exoculata, or "rift shrimp without eyes," lack eyestalks and lenses. But biologist Cindy Van Dover found that reflective tubes on the shrimp's backs contain rhodopsin, similar to light-detecting pigment in human eyes. Though the shrimp can't see, they may sense gradients of light.

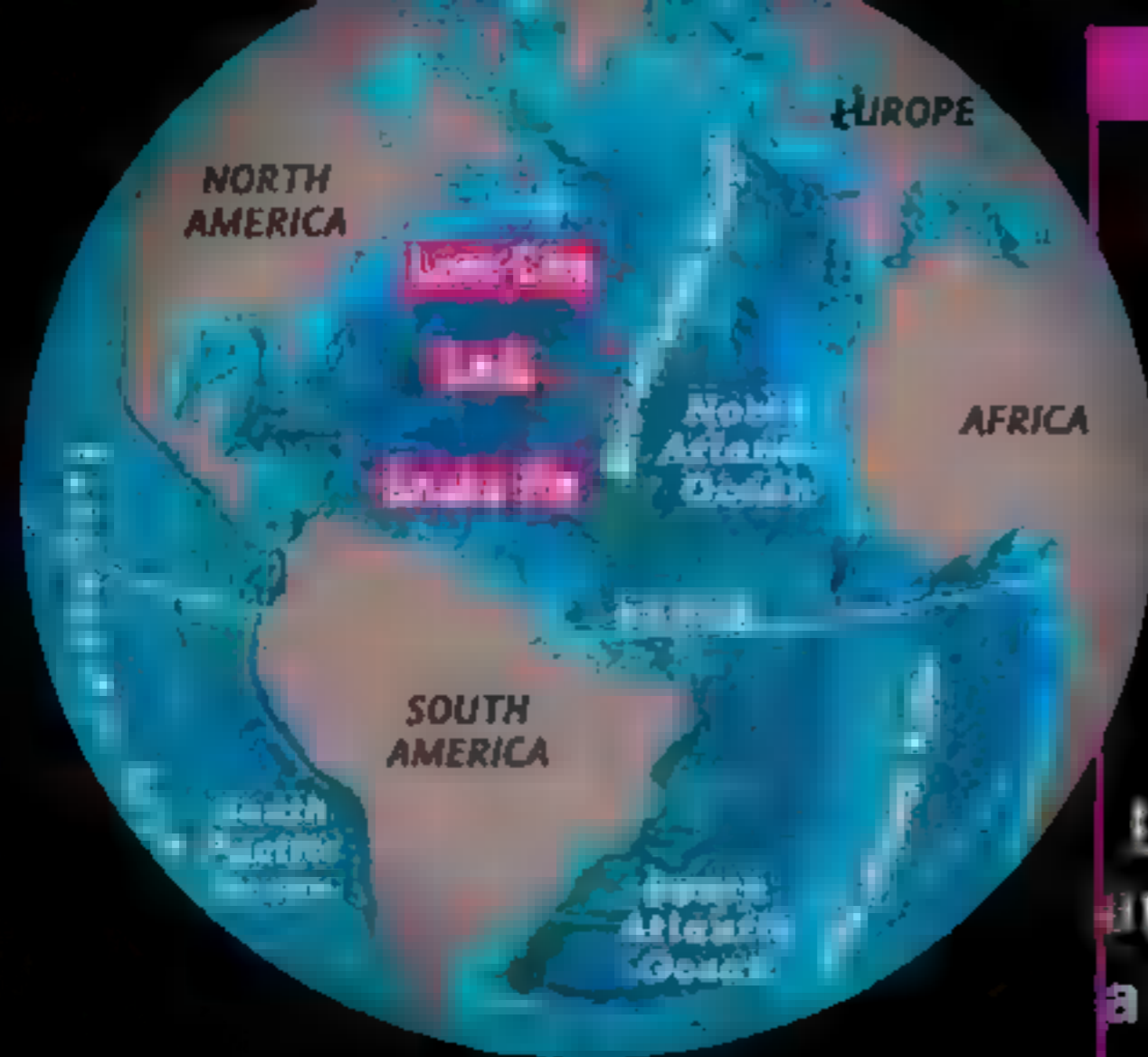
But *what* light? It turns out the hot water from hydrothermal vents glows in infrared wavelengths, invisible to humans but possibly detected by the shrimp. This light may lead shrimp to food-rich chimneys. And because hotter water appears "brighter," shrimp may avoid being stewed.



EMORY KRISTOF



REEVE (ABOVE LEFT)



High-resolution film footage of Lost City, Snake Pit, and TAG (Trans-Atlantic Geotraverse) vent fields along the Mid-Atlantic Ridge prompted a mission that Lutz, of Rutgers University—a major contributor to the project—and his colleagues began a few years earlier on the East Pacific Rise to boost public and scientific understanding of hydrothermal vents.

Late one night in December 2003, as the research vessel *Atlantis* towed a camera some 2,300 feet below the surface of the Atlantic, biologist Debbie Kelley and colleagues spotted a snow-white chimney in water shimmering with heat. Exploring by sub, the team discovered a "rain-forest" of spires, one nearly 200 feet tall. They named the site Lost City—an entirely new type of hydrothermal vent field, where active chimneys emit water heated to a relatively cool 100° to 170°F. This heat results from a chemical reaction between water and a subcrustal rock called peridotite. When the alkaline solution emerges, calcium carbonate crystallizes, building shapes like stalagmites.

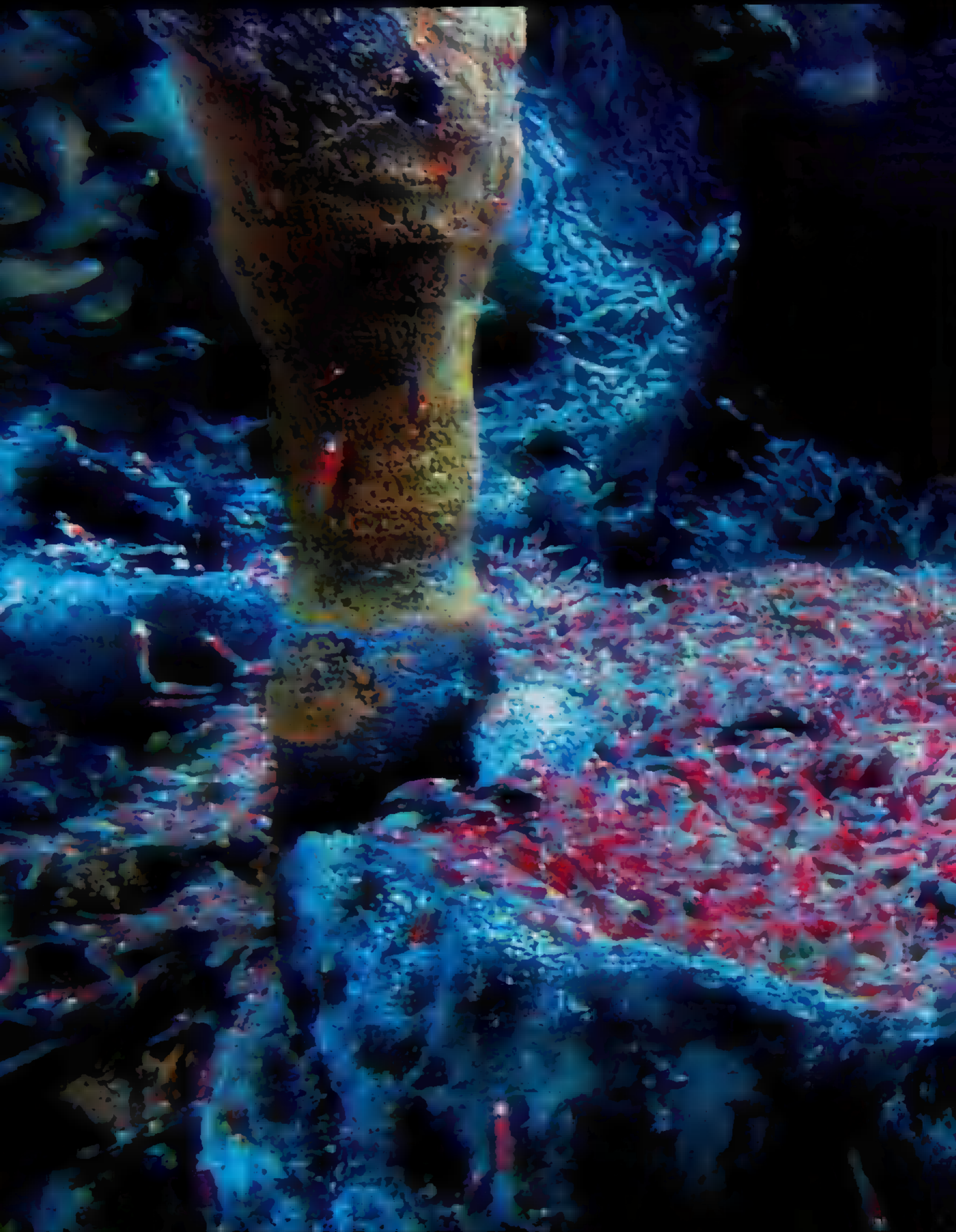
Until Lost City was found, most known deep-sea vents sprang from young, volcanically active regions such as mid-ocean ridges, where sulfide chimneys expel water as hot as 760°F. Yet Lost City's formations lie nine miles from the Mid-Atlantic Ridge on 1.5-billion-year-old rock in an alkaline environment that may be similar to that of early Earth.

Other than dense mats of microbial life at Lost City is scarce. But for an occasional wreckfish (*Heterostichus rostratus*), when we visited to film the site, we were moved by the monochromatic beauty of the carbonate structures. One three-story tower (right) looked like a slender cathedral, lost at sea.



STEPHEN LUTZ, SLP; PHOTOGRAPH BY
STEPHEN LUTZ, DIGITALLY CONSTRUCTED
BRIAN STRAUSS, STAFF (OPPOSITE)
MAP SOURCE: W. SLOSS, NOAA
NATIONAL GEOGRAPHIC MAPS



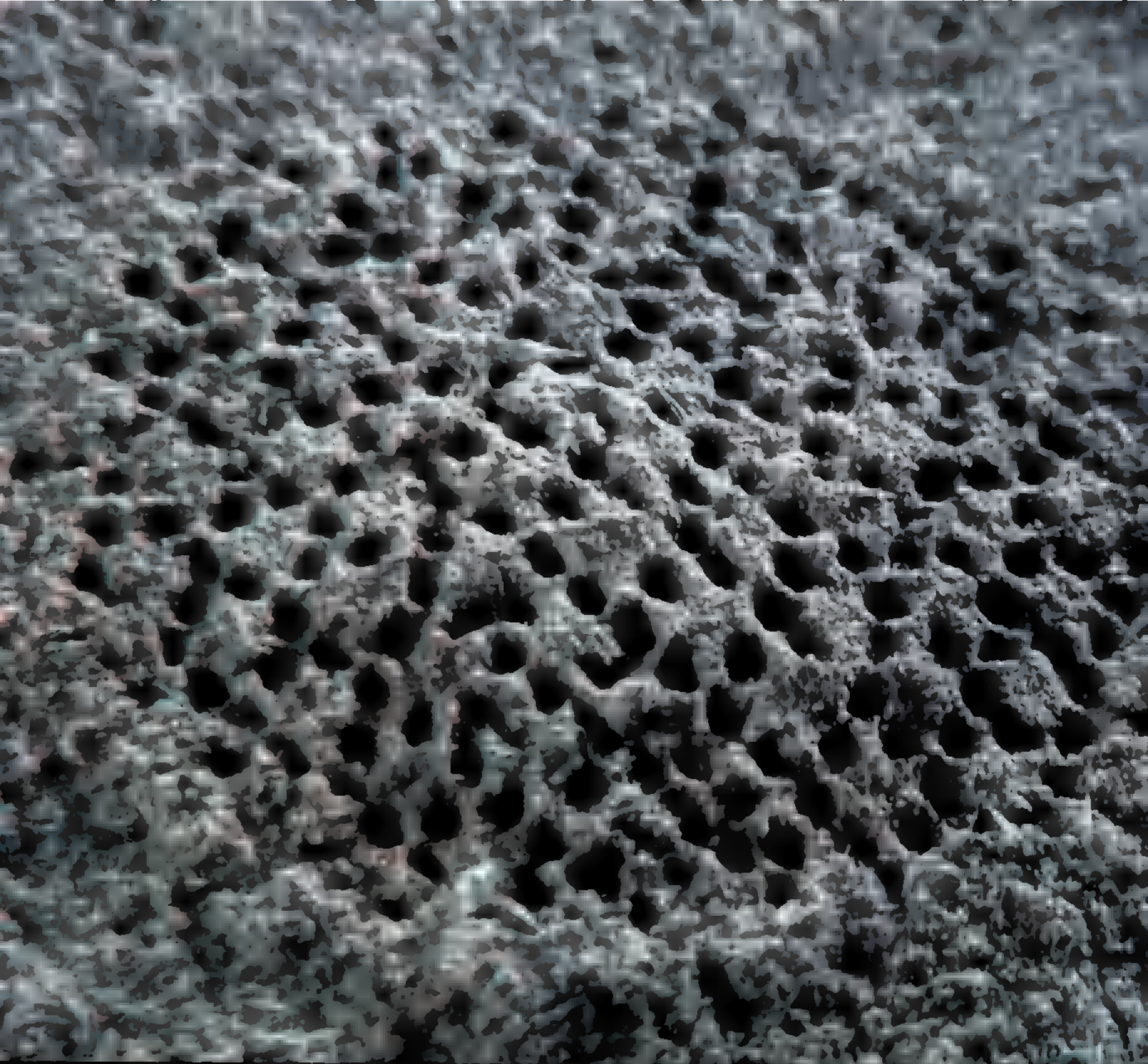


FIT FOR A FEAST

At the Snake Pit site a mineral flareau cradles hundreds of juvenile *Rimicaris exoculata* shrimp and olive-like limpets, while fat mussels hug rocks to the left. Separated from adults for reasons still unknown, the shrimp amass in these

pillars to graze on bacteria and may supplement their diet with internal energy lipid reserves. The black beehive structure at center radiates glowing heat. Yet just inches away temperatures can dip to a cozy 70° to 80°.





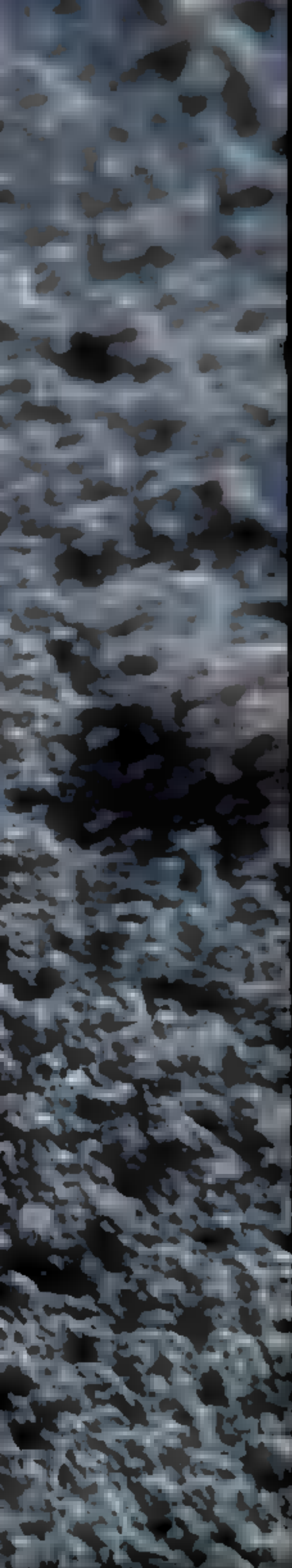
EMORY KRISTOF (ABOVE AND TOP RIGHT); WILLIAM (), SLP (BOTTOM RIGHT)

WHAT BUILT THIS THING?



ANDY KITZANUCK, SLP

Exploring the Mid-Atlantic Ridge in 1976, marine geologist Peter Rona spotted thousands of tiny hexagons near hydrothermal vents he would later discover at TAG. German paleontologist Dolf Seilacher linked the shapes to the 60-million-year-old fossil *Falsodon* *nodosum* (Lüth), a member of a family that dates back 500 million years. Seilacher



LIFE ILLUMINATED

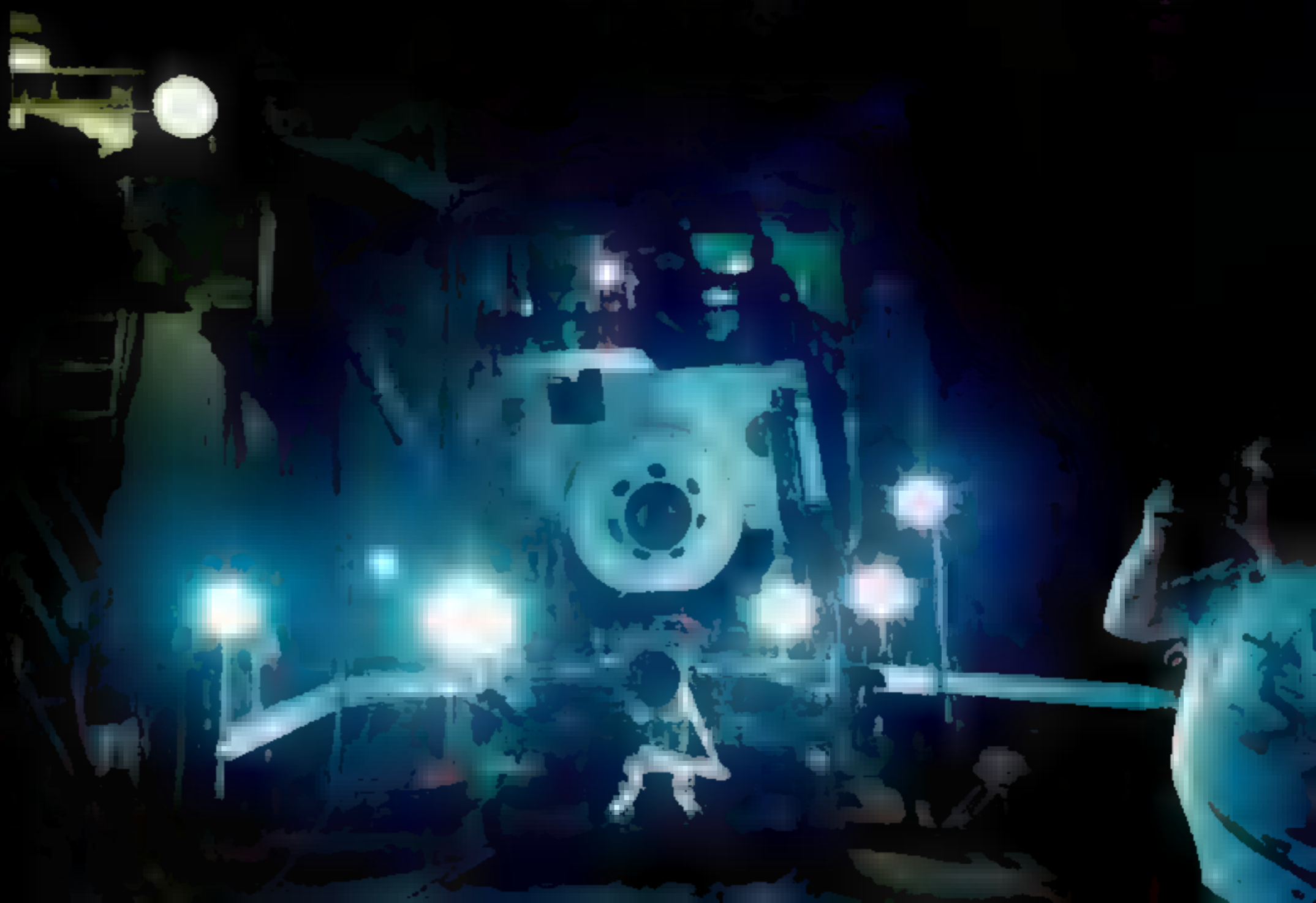
"Humans hate darkness," says filmmaker Stephen Low (above, in the submarine *Alvin*). "To inspire people to open about the deep ocean, we had to light it." That took some doing. Low and Emory Kristof—veterans of filming the *Titanic* wreck—along with sub pilots from the Woods Hole Oceanographic Institution outfitted *Alvin* (below) for the task. Eight 300-watt lights and a 7,300-watt beam-announced spotlight threw light 150 feet out

distance. That light took a lot of juice. "We were just at the edge of running out of power," recalls Bill Reeve, Low's director of photography. Quarters were tight: Only a filmmaker and pilot could fit aboard *Alvin*; the third seat was filled by the IMAX camera. Decades ago it also lit the main viewport, pilots navigated by viewing TV monitors. "It was the pits," says pilot Pat Hickley, who had to avoid the scolding black smokers. But on the movie screen, the large, brilliant images will take people to the bottom of the sea—with a view far better than any paleontologist scientist has ever seen.

includes a worm-like animal curled the deep, then add now. Paine says they may have jelly-like creatures called xenopluteans. No remains have yet been found of the architects.

SCIENCE JOURNAL

Join the story team: Find photos, Web links, and behind-the-scenes features at www.fox.com.

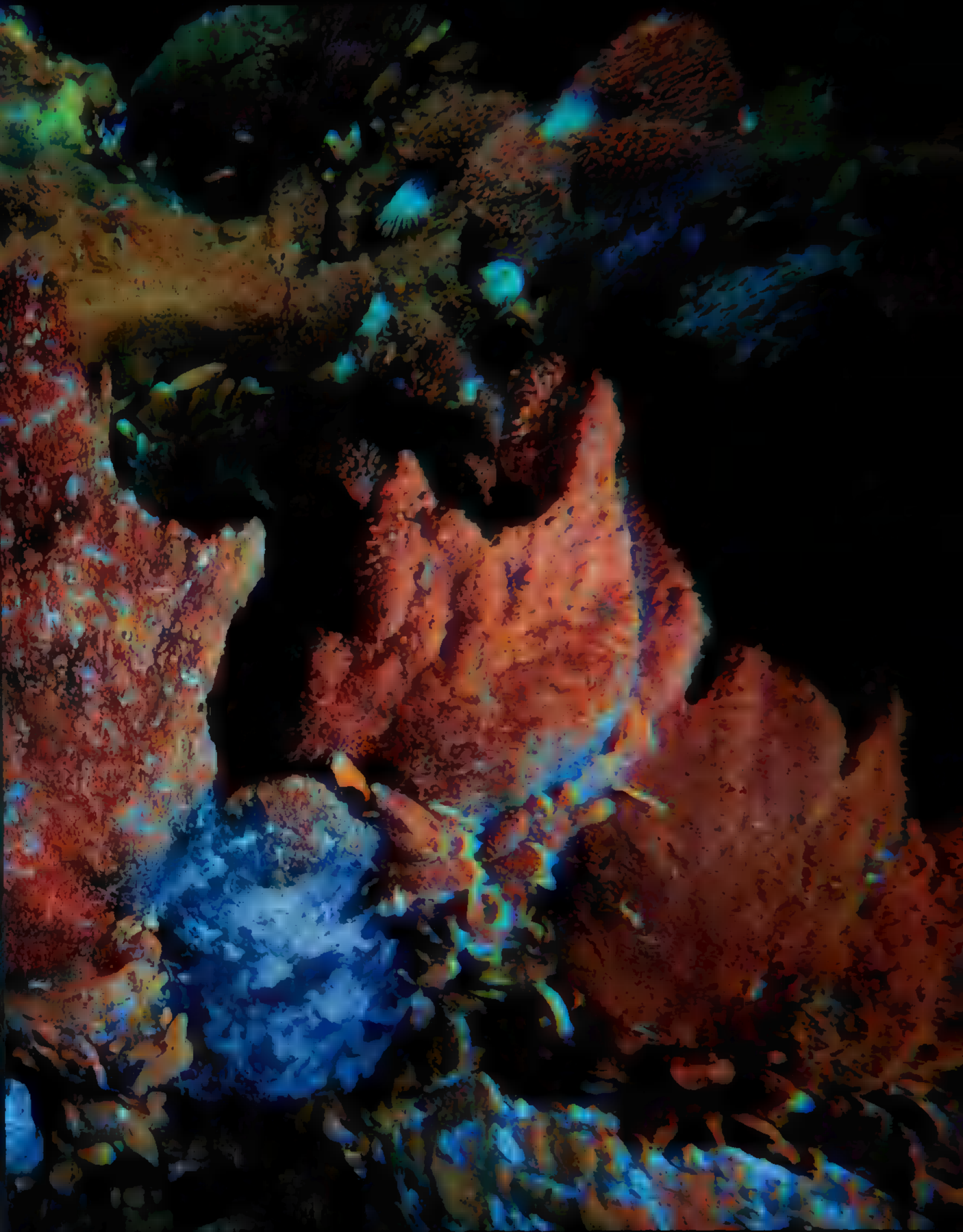


SORCERER'S GARDEN

Whimsy takes shape around a vent at Snake Pit. The metal sulfides that crystallize when a hydrothermal fluid and seawater turn bright orange as the iron in them rusts. Vent chimneys grow fast—

many feet a year. This formation called *Muse* sprouts "pillars" on which anemones and mussels often. Such are the gifts of hydrothermal vents, oases of life in the abyss. □





STEPHEN LOW, BLP



From ghost shrimp
to gray whales,
salmon to ancient forests,
Clayoquot Sound yields
a symphony of life.

Suite

FLIP NURDIN

Low light levels, and a low canopy of plants make for cool forests, and the best birding in the lowland forest on Vancouver Island. Though the ground may not be as deep, most birds are in the canopy, for many species nesting holes are in old pine, natural rot holes, and other log holes. In such forests, many and important birds and perhaps



Precisely where the ground begins is

DISSECTED



hard to say, for the first few feet are a
chaos of moldering wood.



Il y a des moments où l'on se sent vraiment seul, comme si on était le seul à avoir vu ce paysage.



Our dog sleeping in front of a bridge. One of the good things about taking a nap. They make it so much easier to walk.

ff the west coast of British Columbia's Vancouver Island,

Bob Van Pelt tramped ahead across a smaller isle named Meares. We were in woods as old, quiet, green, and wet as a forest can be. Even the air felt soaked. It was hard to tell how much of the moisture came from the chilly rain, how much was fog, and how much was steam rising off the burly figure of a bearded Van Pelt, also known as Big Tree Bob. "I'm hot," he said with a shrug. "Big trees energize me."

When we reached a giant that the locals call Big Mother, Van Pelt, a researcher from the University of Washington College of Forest Resources, took precise measurements with a laser and announced that this western red cedar would probably rank among the ten largest known on the continent. A true ancient, 60 feet around at the base, the cedar had a grove of full-size hemlock trees growing out of her sides and shrublands of huckleberry, salal, and false azalea arising from clefts in her bark high overhead. Thick epaulets of moss padded Big Mother's great limbs. Liverworts and ferns piled out of the mosses, and lichens coated and colored everything in between. She was a forest community all by herself, an organic apartment tower, and the closest thing I had ever seen to the fabled tree of life.

You can try to understand the living world with your head, but sometimes the heart is a truer field guide. Here in Vancouver Island's Clayoquot Sound, a million-acre natural amphitheater where mountainsides embrace a fjord-fingered, island-strewn reach of the sea, you don't have to choose, for every way of knowing nature seems to come into play.

One day I put on scuba gear to descend into another hushed tangle of green not far from Big Tree Bob's Big Mother. I'd been watching mink along the shore, intrigued by the way they swam

Hook-jawed and determined, a male sockeye salmon in the upper Kennedy River wards off rivals as it waits for the adjacent female, foreground, to spawn. Since they need cold, clear rivers to reproduce, salmon are good indicators of watershed health. Only five pristine coastal watersheds greater than 12,000 acres remain on Vancouver Island. Three are in Clayoquot Sound.



out to scamper along floating strands of bull kelp. They kept diving like otters among the giant algae to emerge with crab legs waving from their mouths, and I wanted a closer look.

The water was cloudy with plankton, but a strong morning sun made the depths glow. Sliding overboard from my boat was like being absorbed in chilled jade. Before long I was pulling myself from stalk to frond through a submarine jungle festooned with kelp crabs, decorator crabs, helmet crabs, sharp-nosed crabs, and red rock crabs. I felt like a slow-motion Tarzan in the Lost Kingdom of Mink Meals.

Looking up from the bottom through the kelp-forest canopy with its clouds of surfperch and young rockfish, I could make out overhanging branches of cedar and lichen-draped

Sitka spruce. As if the interweavings of ocean and land in this place weren't obvious enough, an acquaintance told me of a harbor seal in the lower boughs of one spruce, the animal having settled in when the tide was high and snoozed on long after it went out.

The most prolific parts of our biosphere are not necessarily tropical rain forests, as many people assume. Although coastal rain forests in temperate latitudes are much rarer, covering only a fraction of one percent of the Earth's land surface, they hold twice as much organic material per acre as the tropics. Those kelp forests just offshore in the Pacific Northwest can also grow as much biomass per acre as any tropical rain forest, and the region's river mouths and estuaries are wonderfully fertile as well. In

PAUL NICKLEN





Clayoquot, habitats meet and mingle, swapping species and nutrients. The result is an ecosystem that is extravagantly rich and intriguing.

We often speak of Earth's natural wealth. Modern societies spend more and more time arguing over how to preserve it, in what has become one of the most important issues of our age. But what does natural wealth actually consist of? What are the forces behind it? How does it get put together? And why does it tend to accumulate in certain areas? With a superabundance of life-forms both above sea level and below, Clayoquot Sound seemed like a perfect spot to go looking for answers. I was equally curious about the connections between these wild communities and human ones—especially the native Nuu-chah-nulth bands, who have made their home in Clayoquot for at least 2,500 years—and eager to learn how the local people planned to deal with such treasures in the decades to come.

One sure way to diagnose the condition of an ecosystem is to check on the big predators. If the original array is still around and doing well, then the predators must have a healthy variety of prey species, which means that the

underlying habitats supporting lower levels of the food chain are in good shape too. The success of the large, toothy end of the wildlife spectrum in Clayoquot is hard to ignore. Orca fins appear in the channels, locals make a living catching dogfish sharks (sold abroad as Pacific rock salmon), sea lion calls echo across inlets, and Vancouver Island's forests have seen two dozen attacks on humans by mountain lions since the 1960s—more than any other site in North America.

Though it has only 1,400 inhabitants, the small port of Tofino near the sound's southern end ranks as a population center and commercial hub. From it, you can see Vargas Island to the northwest, where wolf packs come and go—paddling across at least half a mile of open salt water each time they do. Black bears and Columbian blacktail deer swim between islands as well. Deer numbers on Vargas have recently dropped, reducing a food source for the wolves. But this being Clayoquot, where biological possibilities appear to multiply along the blurred boundary of land and sea, the wolves are able to stay on by taking gulls plus the washed-up carcasses of other seabirds, seals, sea lions, and an occasional gray whale. *(Continued on page 116)*

Sound of the Saw

Over the past two centuries, three-quarters of Vancouver Island's ancient forest has fallen to logging. Protests in the 1980s and '90s led to the recent designation of an international biosphere reserve in the rain forests of Clayoquot Sound (enlarged at bottom), a fount of biodiversity on the island's west coast. Supporters hope that the reserve—even though it leaves such spots as Pretty Girl valley (left, below plane) vulnerable to loggers—will provide a model for sustainable development.



- Forest**
- Old growth
 - Mountain hemlock
 - Muskeg
 - Logged/second growth
 - Bare ground
 - Park
 - Nuu-chah-nulth village

0 mi / 0 km scale bar.
 FOREST SOURCE: D. LEVERSEE, SIERRA CLUB OF BRITISH COLUMBIA
 NATIONAL GEOGRAPHIC MAPS



the closest thing I had ever seen to
tree of life.



The indigenous Nuu-chah-nulth people of Clayoquot currently number around 700, spread among several villages. "You have to remember," a young woman said, "we had ten times the population a couple of centuries ago." Back then, before diseases introduced by white colonists swept through the native bands, a village chief's principal responsibility was to care for his territory and sustain the natural bounty therein. Management of those living resources was inseparable from spirituality. For instance, if someone needed wood from a tree—weather-resistant red cedar for building or yellow cedar for carving—he would first pray to the tree to thank it. Then he would cut what was needed from the leeward side so the tree would heal more readily than if it were exposed to the wind. Since cedars can live for a millennium, to walk in Clayoquot's forests is to be in the company of some scarred old veterans that likely sheltered the Nuu-chah-nulth here throughout Europe's Middle Ages.

Clayoquot hosts the largest collection of ancient woods left on heavily logged Vancouver Island. Although parts of the area were



safeguarded over the years—in Clayoquot Sound and Strathcona Provincial Park, at the northern end of Pacific Rim National Park, and in small ecological reserves—most of the old-growth forests lay on Canadian provincial lands open to cutting. Beginning in the late 1970s, lumber companies targeted them in earnest. In 1993 thousands of citizens, many from the mainland, arrived to blockade the roads and bulldozers. More than 850 protesters were jailed. Many say it was the biggest display of civil disobedience the nation had ever seen and made Clayoquot



An Eco-economy

A momentous anti-logging demonstration in 1993 put Clayoquot Sound on TV screens around the globe—with unexpected results. Nearly a million people now visit the region annually, fueling a tourism industry worth some 20 million U.S. dollars. Vacationers enjoy outings (above) to look for gray whales, sunflower sea stars (left), and other pieces of the sound’s natural splendor. Logging continues, but one company is taking a different tack. Using helicopters to selectively log old-growth areas (above left), Iisaak Forest Resources, a joint venture of Weyerhaeuser and local Nuu-chah-nulth bands, earned the coveted Forest Stewardship Council certification its first year.

a symbol for the fate of rain forests all along the British Columbia coast.

In May 2000, Canada’s Prime Minister, Jean Chrétien, dedicated nearly 900,000 acres as the Clayoquot Sound UNESCO Biosphere Reserve. Ironically, because such reserves allow sustainable resource use, logging continued. Now, however, it was done by a new company called Iisaak, a joint venture 49 percent owned by Weyerhaeuser, an international timber giant, and 51 percent owned by Nuu-chah-nulth bands. Iisaak is their word for respect.

If you look north from Tofino, you can see old clear-cuts sweeping up and over the shoulders of mountains near Clayoquot’s Catface Range. The structure and multiple ecological functions of the ancient rain forest have been

erased together with the canopy. In their place, bare ground and brushfields stand exposed to the elements while creeks run choked with runoff sediments and debris. The contrast with the original woodlands around them is striking. Yet when I flew over those woodlands with Eric Schroff, then Iisaak’s general manager, he showed me fresh logging sites within the seemingly untouched ranks of conifers.

“It took a social cataclysm in Clayoquot to shatter the old mold,” Schroff said, reminding me that some of the widespread protests that brought a halt to indiscriminate logging were initiated by tribal leaders. After our plane landed on floats near Catface, he led the way on foot to show me the latest version of timber management—cutting units that resembled small



Sea Lions vs. Salmon Farms

Its bite equal to its bark, a young Steller's sea lion shows why it's one of the sound's top predators. Though endangered in western Alaska, these sea lions are thriving in Clayoquot Sound, sometimes raiding the pens of another booming species: commercial salmon farmers. Salmon farmers legally shot 5,000 sea lions and seals over the past decade. Mass graves like the one at right caused a public outcry, but environmentalists say the slaughter pales in comparison to the threats the penned salmon pose to wild fish through disease, pollution, and competition from escaped fish.

openings within the forest caused by natural forces such as windthrow, root rot, or a minor slump of earth on a hillside.

"First, you go out and protect resources by putting streamsides, coastlines, and key wildlife habitats off limits," he told me. "Then, and only then, do you go logging. OK, some trees are gone now. But the forest is still here. We take logs out by helicopter so we don't have to build many new haul roads. Our costs are higher than some commercial operations, but you'll find a lot of support around here for trying to do things right."

Given the public scrutiny focused on Clayoquot, the first sites sawed by Iisaak were intended as showcases. How long such extra-selective logging will continue in the face of demands to bump up production is anybody's

guess. Nevertheless, it certainly qualifies as one of the best attempts yet to harvest trees from a temperate coastal rain forest while also giving every other living thing its due.

Ten feet of moisture falls out of the sky here annually. Some spots nestled below cloud-catcher peaks see more than 20 feet. That much precipitation translates into a billion gallons of raindrops per square mile in a typical year. "My home is in Tofino," goes a local saying, "but I live in rubber boots." Winter storms through in infinite shades of gray. There are weeks when you don't even think of it as raining until the constant drizzle gives way to larger dollops. While summer skies can be brilliant blue, that still doesn't mean the coast is clear. Ask the

surfers at Long Beach in Pacific Rim Park. They don't say August; they call the month Foggest.

The richness of life in Clayoquot's forests is largely tied to abundant water. Here is the reason spruce can rise 200 and 300 feet tall and cedars bulge as big around as living rooms. Water is why the epiphytes, or guest plants, on one of those titans may weigh much more than the tree's own foliage. Along with some alders and cottonwoods, big-leaf maples send roots from their own trunks and limbs to tap the soil that develops beneath all the ferns and mosses and other vegetation thriving there.

Part of the stupendous productivity of temperate rain forests comes from tree-dwelling lichens. Some have the ability to perform the everyday miracle of absorbing nitrogen gas from the atmosphere and transmuting it into organic compounds essential to growth. Eventually dropping onto the forest floor like manna from heaven, the lichens are a key winter food for

dust lichens that painted chartreuse shades over stones, cedar trunks, and even the wooden handrails on a park boardwalk. He told me that scientists have identified more than 700 chemicals made by these organisms and that some show promising pharmaceutical properties. The amount and variety of lichens tend to increase as a woodland ages; parts of Clayoquot's forests have probably flourished intact for three or four thousand years.

Technically, a lichen is a symbiotic partnership between a fungus and either algae or cyanobacteria. "You could call them fungi that discovered agriculture," Goward said during our ramble. "But the result is neither a fungus, plant, nor animal. I think of lichens as a kind of doorway between organisms and ecosystems. Look out one direction, and you see individual things; look the other way, you see processes, relationships—things together. This is the next level in understanding biology."

Rich as a rain forest's epiphyte load is, the cool-climate jungle only gets richer underfoot. Precisely where the ground begins is hard to say, though, because the first few feet are a criss-crossed chaos of moldering wood.

Clayoquot's largest virginal watershed is that of the Megin River, which runs from the crest of the Vancouver Island mountains down through Strathcona Provincial Park to Shelter Inlet in the heart of the sound. During a kayak trip on the Megin's cold, clear windings, I kept going ashore between the rapids for exploratory strolls in the bottomland forests. Except that I never could stroll. Instead, I hoisted myself over logs, sank right into some gone soft as

soufflé, and wished I were one of the coast's red squirrels that spends most of its life traveling from branch to branch far above the rain forest floor.

My explorations that day convinced me that there is at least as much life in a huge conifer after it has fallen as when it was standing. A cedar on the ground may take five centuries to disintegrate. During that time, it will accumulate two to three times its original allotment of nitrogen and phosphorus, thanks to all the worms, mites,

(Continued on page 124)



PAUL [unreadable] (OPPOSITE)

Clayoquot's deer and herds of Roosevelt elk. At the same time, they can supply one-quarter to one-half of the nitrogen that fertilizes rain forest soils. The tiny, often overlooked players in an ecosystem power much of its grandeur.

More than 500 lichen species flourish in Pacific Northwest rain forests. A number of them were discovered by Trevor Goward, a specialist affiliated with the University of British Columbia. When we hiked the coast together, he pointed out types named lipstick pixie, fairy puke, and seaside centipede lichen, along with



1. Fireworks exploding in the night sky. (Image by iStockphoto.com)



The Circle Unbroken

After defending her nest for as long as she can swim upright, a female sockeye salmon drifts back into an eddy to die, becoming a vital source of nutrients for the stream. The massive influx of salmon carcasses is the key to healthy river ecosystems in the region, eventually benefiting everything from beetles to offshore orca populations. The more carcasses, the more insects hatch for the rough-skinned newt (above right), and the more animal droppings for the banana slug (right), king of the decomposers. More than 800 of British Columbia's salmon stocks are at moderate to high risk of extinction or have already disappeared, with much of the decline attributed to habitat destruction.

beetles, and other organisms slurping their way through the wooden carcass. The fallen tree also stores tons of water like a sponge, helping maintain the high humidity and moderate temperatures crucial to the life cycles of so many other species from liverworts to tree frogs.

The cool, moist conditions of this western red cedar/hemlock zone also support a spectacular diversity of fungi—several thousand species of mushrooms and molds. “Our rain forest is like a tropical forest turned upside down,” said Bryce Kendrick, a fungi expert overseeing a research project in Clayoquot. “Instead of most of the action being in the plants, it’s underground. There are several kilometers of fungal threads in a pinch of soil here.” Many form symbiotic relationships with

the roots of vegetation. Known as mycorrhizal fungi, they collect moisture and nutrients via their own rootlike networks and pass them along to plants in return for some of their energy-laden sugar.

Plants invested in this kind of joint venture grow faster, handle environmental stress better, and enjoy higher rates of survival than those without. Often, the microscopic threads link plants belonging to entirely different species: small trees to larger ones with greater soil resources. In fact, nearly all vascular plants use fungi to tap into food collected by their neighbors. Join this vast, hidden network, and you’re tied into the forest in a whole new way—one that makes it harder than ever to say where the individual ends and the community begins.



In natural systems, everything finally partners with everything else to some degree. The more linkages, the faster biological wealth spreads and multiplies. One autumn day I lay among bright stones on the bottom of Kennedy River in the eastern part of Clayoquot, breathing through a snorkel and pondering anew where the forest ends and the ocean begins. Nearby, seals that had swum miles upriver were chasing sockeye salmon through the fresh water pooled in Kennedy Lake. All kinds of nutrients collected from distant reaches

of the sea were thrashing upstream and bumping my legs in the form of more sockeyes on their way to spawn. And pound after pound was heading overland as black bears wading on either side of me caught the scarlet fish, took them to the woods to eat, then left the carcasses to compost along with extra nitrogen concentrated in urine and dung.

Out of the corner of my face mask I saw Steller's jays gliding down from cedar branches to wade after loose salmon eggs aswirl in a shallow eddy. I also saw eagles, gulls, ravens, mink, otters, and raccoons dining on the fish or their eggs or both. Deer and

ducks would come to nibble the salmon carcasses; even little chickadees and winter wrens have been seen pecking at them. A local guide told me of watching trout bang the sides of gravid female salmon, forcing out eggs to gulp.

In all, more than 130 species of vertebrates eat salmon at some stage of the fish's lives. Many transfer those nutrients into the forest, boosting the growth rate of vegetation. Studies show that recycled salmon can account for an average of 20 percent of the nitrogen in streamside vegetation (up to 40 percent in the case of

huckleberry bushes), and 25 to 50 percent of the carbon and nitrogen in aquatic insects and salmon fry. Like a fallen rain forest tree, a spawning salmon doesn't die so much as begin serving the ecosystem in different ways. From that perspective, some of Clayoquot's monumental evergreens embody hundreds of generations of big, sea-grown fish and of the bears, eagles, wolves, and other animals that transport them. Likewise, young salmon embody the forests' roots, leaves, lichens, and grazing slugs that feed organic wealth back into streams and their estuaries.

A separate pulse of nutrients comes from the ocean to the far reaches of Clayoquot's bays each spring when the herring spawn. As recently as the middle of the past century, the schools that swept through left much of the intertidal zone silver with their eggs, pasted to rocks and seaweed.

Overfishing seriously thinned herring numbers. Yet Vera Little, a Nuu-chah-nulth elder I met on Flores Island, told me that family members still place boughs along the shore and haul them up coated with roe. Sold to Japan as a delicacy, eggs are the main product of British Columbia's commercial herring industry today. The gutted fish are used for bait or animal feed.

The sound also supports salmon farming. Farmed salmon are now British Columbia's largest agricultural export, amounting to about 45,000 tons annually, twice the weight of wild salmon caught in the province in 2001. Not that everyone regards having nearly two dozen large pen-rearing operations in Clayoquot as something to be proud of. Critics worry about the buildup of wastes and possible spread of diseases to wild fish stocks.

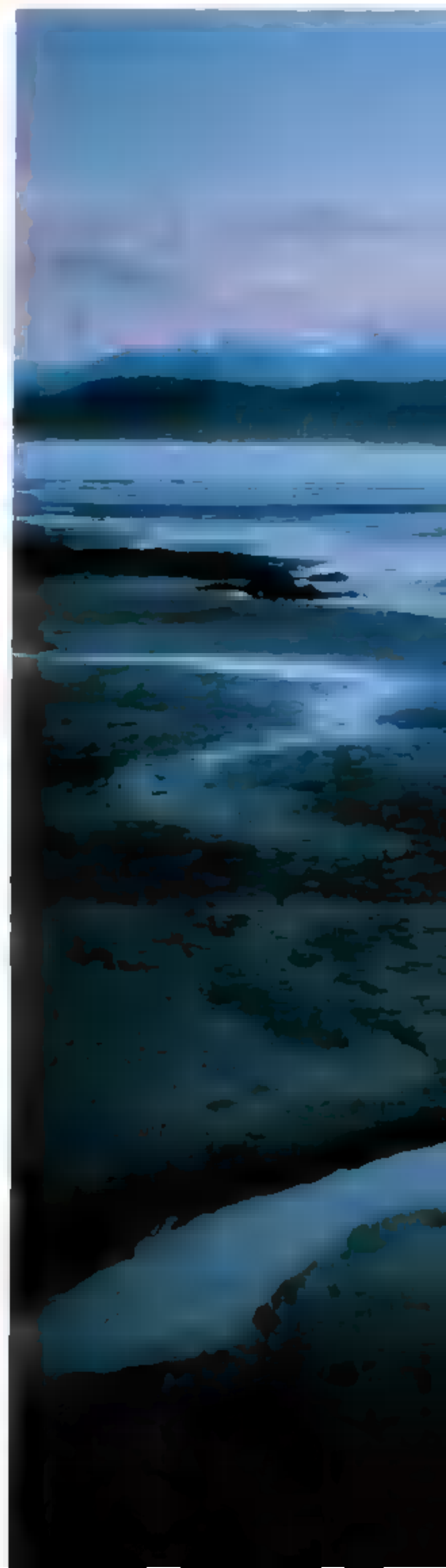
Clayoquot's wild salmon feed upon the area's silver shoals of herring. The little fish are also a mainstay for the largest predators in the ecosystem, humpback whales. Once hunted by native crews in long canoes, the humpbacks in turn helped sustain the Nuu-chah-nulth, who savored the meat and traded the giants' rich oil for goods from other tribes. But industrial whaling by whites took over and depleted populations of humpbacks until late in the 1960s. On the increase today, these whales once again plunge through the outer waters of the sound, joined

in the fish-chase by tufted puffins, rhinoceros auklets, and other seabirds from breeding colonies on the rocky isles scattered offshore.

Gray whales are more common, having recovered earlier from the commercial slaughter, and they tend to stick closer to the coast. Jim Darling, who has a home in Tofino, is a leading authority on Pacific grays. "The other day," he told me, "I ran across Two Dot Star, a whale I first saw here in 1974. I usually identify 35 to 50 grays in Clayoquot Sound through the summer. This is part of a larger Pacific Northwest population." Most migrate to Mexico for the winter, but now and then a gray will stay around all year. Whale-watching brings an estimated five million dollars (U.S.) annually into Tofino. For the boat operators these animals are practically spouting cash.

Later, we watched the million-dollar mammals plow cloudy trails through shallows where

One of Vargas Island's habituated wolves scavenges a tidal flat. Revered by the region's Nuu-chah-nulth people as mythic beings that could take many forms, the wolves now face the same uncertain fate as the sound. Keepers of Clayoquot must decide: What should be wild, what should be tamed, and what shape should it take in the future?



they barely had enough water to float. “These are whales that make much of their living on the beach,” Darling commented. “It’s just that they use it at high tide.” The whales withdrew with the water, and their feeding grounds soon stood revealed as a vast mudflat with waves of migrating shorebirds skittering across it. Thousands of shallow pits the length of rowboat hulls patterned the surface. Each represented a mouthful sucked in by a whale that then used its tongue to force the sediments out through baleen plates, trapping a tasty tangle of ghost shrimp and *Mya* clams. With every shrimp came creatures that had shared the space inside its muddy burrow—scale worms, more clams, pea crabs, and tiny gobies—plus copepods living under the shrimp’s exoskeleton and others clinging to its gills.

Strange how ecosystems and economies work. Grown from a mix of nutrients flowing out of forest rivers and in from the sea, these tiny,

gunk-eating, mud-tunnelers and their even more obscure roommates are really the wildlife that help nurture the business folk, from local watermen who have jumped into the whale-watching business to motel owners, bankers, and grocery clerks ashore.

Each organism in an ecosystem is bound to every other in more ways than we can fully understand. Our wildlife heritage lies as much in organic processes and communities as in the individual creatures that tend to catch our attention. The further science probes the nature of things, the closer it comes to time-honored native concepts about living beings transforming into others, a worldview summed up by the Nuu-chah-nulth as *hishuk-ish ts’awalk*—everything is one. □

WEBSITE EXCLUSIVE

Find more images, field notes, and a listing of websites and resources at nationalgeographic.com/ngm/0302.



83422

All Eyes on Idaho's Finest

BY TOM DWORETZKY PHOTOGRAPHS BY NINA BERMAN

The days have grown short in Driggs, Idaho, and Paul Paulsdorf, a third-generation farmer, agrees to take a break from harvesting his 500 acres of seed potatoes and packing them into a half dozen of the giant Quonset-hut cellars that pepper the valley. He leads me into one of the dark cellars like a proud parent. Standing before a heaping pile of tubers, I can see the top of a pair of

floury fingers. Paulsdorf says, "We have to manage the temperature with care to keep them from sprouting to begin with. Without our studies, the tubers would rot in the ground or go to a full-on sprout in a week. In the spring, the disease-free seed potatoes will be shipped to growers in the Pacific Northwest to be cut—one size per piece—for planting."

It is a fact that the high children in this Mountain State will be let off school no less than to help with the harvest and packing work under the sun in hot summer months. Our millrace, too, has been built to grow the seed potatoes, but the high ground is a place that has



Open since 1953, the Spud Drive-In draws lots of patrons—maybe too many these days. With new houses coming closer, the Spud had year and its first noise complaint.

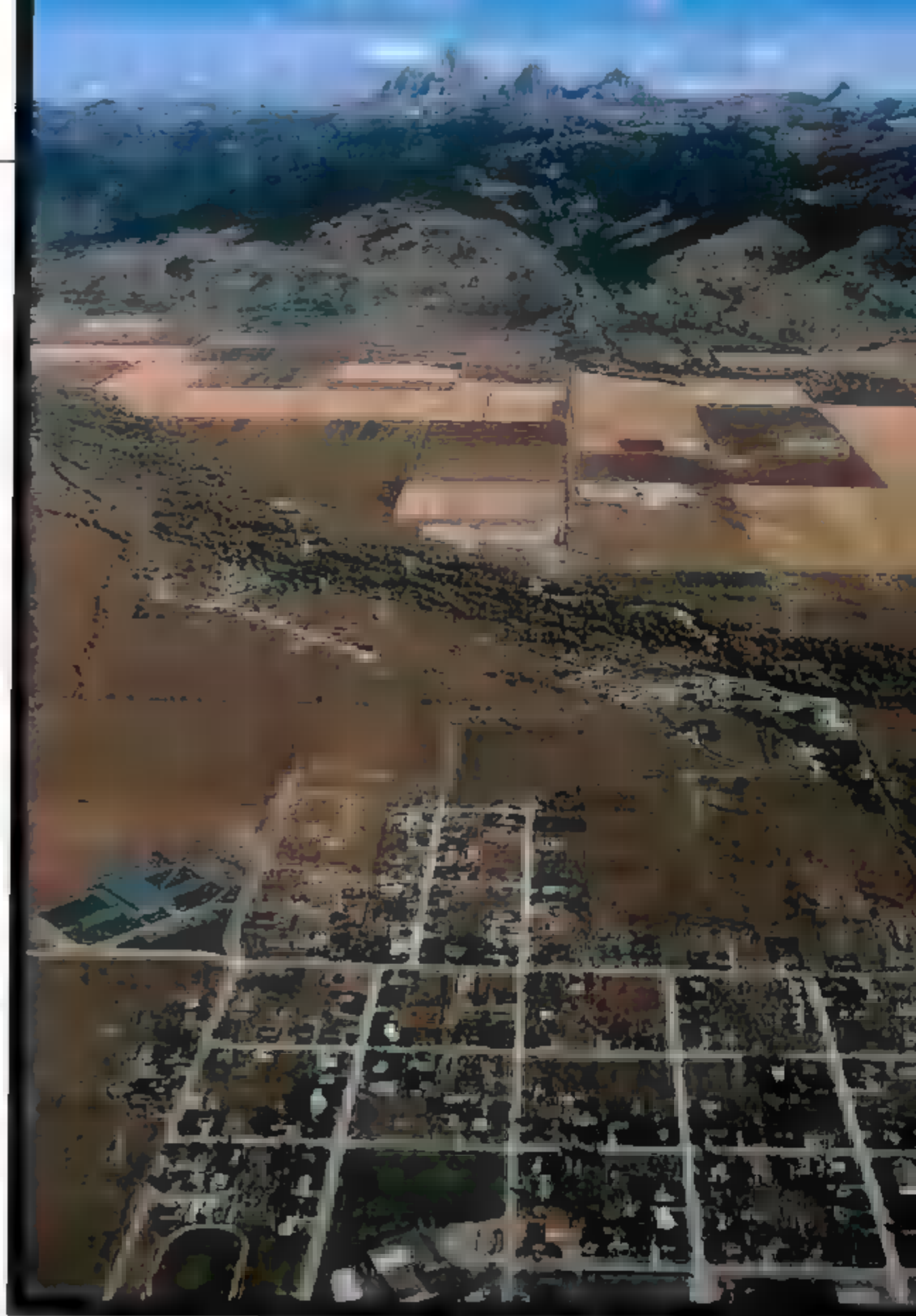
DRIGGS, IDAHO

He's been trying to retire for years, "but Paris won't let me," he says with an easy laugh as we stand in the soft, brown dirt by the huge crossover machine he's been driving all day. The crossover, bouncing side to side over the deeply rutted field, digs up potatoes from one row and dumps them on top of another, so the harvester can suck up a mouthful at once and conveyor-belt them into potato trucks driving slowly alongside. The work sends a haze of dust into the thin mountain air.

When the harvest is in and bitter snows slow valley life to a crawl, Paris Penfold will turn to other jobs, like most folks around here. He is, after all, the bishop of a local Mormon church. And he is a master carpenter, having built his spacious house, including its elaborate cabinetry, and much of his own furniture. From the windows above his sink you can see the soaring, forested Tetons across the fields and catch sight now and then of coyotes—which with disheartening regularity have made off with a long line of family cats.

Penfold's son, Wyatt, is a fourth-generation potato farmer. But by the time he takes over his father's place, few of the neighbors will even know what a crossover is. More and more farms like Penfold's are giving way to 2,500-square-foot log retreats. Nestled between the Tetons and the rolling Big Hole Mountains, Driggs has become a haven for outdoor enthusiasts, with fishing, hunting, climbing, skiing, paragliding, ballooning, snowmobiling, even skateboarding. Skateboarders call fresh asphalt on a twisting mountain road "black powder," after the white powder of newly fallen snow. Nearby, 780 acres are being transformed into a golf resort.

The seat of Teton County, Driggs lies just a short drive across Teton



Just west of the Tetons in ideal seed-potato country, Driggs now attracts skiers, mountain bikers, and various other "move-ins." "Come enjoy it," says native spud farmer Wyatt Penfold (below, at right, with Clair Hillman). "But don't push me out."



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DRIGGS, IDAHO

Pass from Jackson Hole, Wyoming, “where the billionaires are driving out the millionaires,” as locals like to say. Movie stars, too, make regular appearances in Driggs. Harrison Ford parks his planes at the Driggs airport, a fact not lost on Kristal Nagle at her family’s Corner Drugstore. A college junior, the brunette former high-school cheerleader says she wants to get married and have 12 kids. She laughs. “I’ll have to marry a rich man.” She has a huge crush on Ford.

August Busch III of Anheuser-Busch and Paul Allen of Microsoft fame have spreads in the valley surrounding Driggs. “Lot of money, though you don’t see it here,” one local told me.

What you do see is a community struggling to hold on to its way of life as “move-ins” and new ideas flood into town like spring snowmelt. Clair knows about change. After his wife passed away seven years ago, he got involved with a move-in. “I married a ski bunny, 26 years my junior. But

“They’re alive. We have to manage the temperature with computers to keep them from sprouting.”



she ran off. I still see her, though. She stays with me when she comes out to ski. Lives in Maine now. She’s getting her Ph.D. in forestry.”

On Main Street a couple of Mexican restaurants share space with the drugstore, a Laundromat, the Dark Horse Bookstore, and a restaurant-gallery-clothing-jewelry store called Miso Hungry. Over an espresso I learn about the town’s farmers, skiers, and hired farmworkers from Jeanne Anderson, owner of the Dark Horse and a move-in herself. “The high school is the real melting pot for old-timers, move-ins, and the Latinos here,” she said. It’s also a place with a sophomore curse. For each of the past several years, a teenager has died. Last year it was a boy wrecking a car. This year another boy, Robie, from a drug overdose.

It hits home for me a few days later, over breakfast at Miso Hungry

It takes three days for a worker with a remote-controlled conveyor to load a potato cellar with three million pounds of Russet Burbanks. If left untended the spuds would become hot potatoes—radiating heat and ruining the crop.

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DRIGGS, IDAHO

with Dave Wade and his 11-year-old son. Dave, a waiter at a Jackson restaurant who also sells handmade candles, talks proudly of his son's passion for freestyle skiing. But the boy is mighty quiet.

"He had a really good friend, almost a brother, who died recently."

I nod sympathetically. "Robie?" His son nods yes.

"It's real hard when something like that happens," I say, meeting his son's eyes.

He looks me right back for an instant, unblinking, making contact with an adult as kids rarely do. Then he looks away.

Comfort comes in many forms, and in Driggs on this Friday night it comes in the crowd of families and teenagers gathering at the Spud Drive-In two miles south of town. Though it's quiet and dark, you can't miss the towering wooden screen and the dilapidated flatbed truck sporting a concrete potato.

Sara Wood, wearing a purple shirt with "tease" written on it in sequins, takes my five dollars and directs me to the refreshment building, where her father, Richard, runs the projectors and her mother, Dawnelle, has covered every inch of the ceiling with old vinyl records. She's also put out for display her budding line of tater-themed T-shirts.

During the double feature—*Osmosis Jones* and *American Outlaws*—some people are actually watching from their pickup trucks and cars. But most are on their way to the snack bar or are standing outside, talking, laughing, seeing and being seen. Orders crackle over the PA system for fries and Gladys Burgers (named for a previous owner). The meat's real lean, Dawnelle says, that's the secret to the burgers. And the fries? Made from Idaho's finest. □



"We like the movies, but we really like the food," says 15-year-old Christine McKague (below) at the Spud Drive-In. Now running the show, Richard Wood (above) used to be the theater's drink cooler before he took over in 1987. "You couldn't blow him out of here with dynamite," says his wife, Dawnelle.



MORE INFORMATION

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PACIFIC SUITE

It's All a Blur

Hundreds of western sandpipers zoom into Vancouver Island's Clayoquot Sound to gorge on worms and crustaceans exposed on beaches at low tide. "They banked and twisted and turned like little fighter jets," says photographer Joel Sartore, who spent a week in spring downpours waiting for the birds to fly into focus.

The story's photo editor Kathy Moran and design editor David Whitmore liked the "poetic frenzy" of the image, but it was cut to create room for more pictures and text in "Shattered Sudan." "We're so focused on the articles we're working on, but there comes a time when we have to step back and look at the mix of stories in the whole issue," says Kathy. "The Sudan story deserved more space, more weight."

WEBSITE EXCLUSIVE

Cut it or keep it? Find out more about what tipped the balance for this photo and send it ■ an electronic greeting card at nationalgeographic.com/ngm/0302.

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Mother Nature's Energy Bar

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SUDAN

Under House Arrest

Working in a war zone

A bellhops. That's what photographer **Randy Olson** called the Sudanese gunmen town of Juba when he was confined, under house arrest, until the next time the armed government security escort showed up. The house he lived in belongs to one of the richest men in Sudan, but has been in ruin. "You sweat like a pig at night, and the blood of everyone else who has sweated through your mattress wafts up around you," Randy says. In private, he was able to watch CNN, thanks to a satellite dish mounted in the municipal square, photographed through a kitchen screen)—at least when the area wasn't hit by one of the frequent mortar bombings.

As one of the first American

photographers in modern Sudan in two decades, Olson faced other obstacles. For one, night time increased his risk of kidnapping and film theft. He missed the regional film market under Egyptian rule, his assistant's militia, where he figured out if he could afford to risk.

One day he called his wife, photographer Melissa Fisher, on a satellite phone (below). "It was hot and humid, I was covered with mosquitos carrying flies, and I had just enough food and water to survive the next few days. I call Melissa, who's in an air-conditioned bureau in Kentucky planning a \$2-million color racehorse. Two photographic assignments bridging two worlds about as different as I can imagine."



YAHIA IDRIS (ABOVE); RANDY OLSON

GNIMMENT

OVERING THE WORLD





OLSON

SUDAN

Refugees From an Endless War

Wad el Bashir camp outside the Sudanese capital of Khartoum is “a devastatingly bleak maze of mud huts and dirt lanes baking under the desert sun,” says **Paul Salopek**, two-time Pulitzer

Prize-winning foreign correspondent for the *Chicago Tribune*, former *GEOGRAPHIC* staffer, and chronicler of Sudan’s woes. The refugees around him in this photo are listening to elders, mostly displaced Dinka and Nuba people

from the south. “They’re squabbling over who has the right to be a spokesman for the group,” says Paul. “Typical Sudan.”

Paul’s travels took him into areas controlled by the Khartoum government and those held by rebels. One night, when camped with a rebel brigade on a vast savanna, he awoke in the dark to the muffled clanking of weapons and “the soft shuffle of sandaled feet”—the rebels were mobilizing for an attack. At dawn he found himself alone among the thorn trees save for a handful of rear-guard soldiers and the lifeless campfires of the departed troops. “Somehow, it was a terrible sight,” he says.

All the Sudanese people Paul met were unfailingly hospitable and gracious. “I was often puzzled how such nice folks could be killing each other with such implacable determination.”

WORLDWIDE

Wildlife biologist, journalist, hiker, diver, and ■■■ kayaker **Douglas Chadwick** admits he wasn’t impressed when he first visited Vancouver Island’s Clayoquot Sound. “I thought it didn’t look all that biologically diverse compared with the tropics. But it’s all about knowing how and where to look. Once I started hanging out with the lichenologists and the fungi people and the slug people, new dimensions suddenly opened up.” A gastropod specialist showed him how to look for slugs and snails, and soon Doug saw “herds of them, including hundreds or even thousands of pinhead-size snails per square yard.”

Her full name is Elizabeth Louise Johns, but everyone calls her Louise. She’s ten years old, and while her father, senior editor for illustrations **Chris Johns**, was

photographing in the Pryor Mountains on the Wyoming-Montana border for this month’s article on Sacagawea, Louise got the urge to take pictures of wild horses herself (right). Throughout a month on the road, including a week camping in all kinds of terrible weather, “she never complained,” says her father. “I do my job better when she’s with me. And she has this gift with horses—wherever she is, they come to her.”

Sometimes the hardest part is getting home. Photographer **Meredith Davenport** had expected a ride to the airport, but it never came. In the mountainous Nuba region of Sudan there’s only one alternative: walk. So Meredith, her Nuba guide, a pair of Sudanese



MODEL

soldiers, and a handful of cooks and bearers set out on foot across a mountain valley for the nearest village. “It was about 100°F when we started,” Meredith recalls. “We walked from 4 p.m. till 6 a.m., with a couple of stops for rest. I started with only a little water, and it went fast. I’ve never been so dry in my life.”

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Flashback



EDWARD S. CURTIS

SACAGAWEA

The Posing Question

Did this Hidatsa hunter really catch this eagle? Maybe. Photographer Edward S. Curtis spent years documenting Native American cultures—including the Hidatsa, the people among whom Sacagawea lived as a war captive. Fourteen of Curtis's images (though not this one) appeared in the July 1907 *GEOGRAPHIC*, in which he says, "Being photographs from life and nature, they show what exists, not what one in the artist's studio presumes might exist." Yet Curtis is known to have posed his subjects, going so far as to supply them with props.

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